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May 1983

CALCULATED AIR QUALITY IMPACT OF EMISSIONS FROM THE INTERMOUNTAIN GENERATING STATION (IGS)-- TWO UNIT CONFIGURATION

Prepared By:

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W. R. Hargraves

Prepared For:

INTERMOUNTAIN POWER PROJECT

5250 South 300 West

Murray, Utah 84107

H. E. Cramer company, inc.

UNIVERSITY OF UTAH RESEARCH PARK

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EXECUTIVE SUMMARY

BACKGROUND AND PURPOSE

The construction and operation of the 3,000-megawatt coal-fired Intermountain Generating Station (IGS) at a site near Delta, Utah has been approved by the Utah Bureau of Air Quality (UBAQ), the U. S. Environmental Protection Agency (EPA) Region VIII and the U. S. Department of Interior. This approval was in part based on a dispersion model analysis of the air quality impact of emissions from the plant (H. E. Cramer Company, Inc. Technical Report TR-78-450-01, August 1978) which indicated that the plant would comply with the National Ambient Air Quality Standards (NAAQS) and the Prevention of Significant Deterioration (PSD) Increments for Class I (pristine) and Class II (moderate growth) areas. The August 1978 air quality impact analysis was subsequently updated in June 1981 to reflect slight changes in the stack configuration (H. E. Cramer Company, Inc. Technical Report TR-81-478-02, June 1981). The results of the air quality impact assessment described in the June 1981 report also indicated that the IGS would comply with the NAAQS and the PSD Increments.

The Intermountain Power Project (IPP) has recently notified the UBAQ of design refinements and a reduction in project size from four to two generating units. The purpose of this report is to provide IPP with the results of a dispersion model analysis of the air quality impact of emissions from the present two-unit configuration for the IGS. Because detailed engineering estimates of low-level particulate emissions from operations such as coal handling and haul road traffic are now available, this is the first air quality impact analysis of the IGS by the H. E. Cramer Company that addresses the low-level particulate emissions.

CALCULATION PROCEDURES

The dispersion model calculations described in this report and in the August 1978 and June 1981 reports were performed using the SHORTZ/LONGZ complex terrain dispersion models (EPA Reports EPA-903/9-82-004a and 004b, March 1982). As discussed in Appendix H of EPA-903/9-82-004b, the SHORTZ/LONGZ models have closely matched observed SO_2 air quality in both urban and rural areas in studies performed for EPA by the H. E. Cramer Company during the last 8 years. The SHORTZ/LONGZ models contain algorithms to account for the effects on ambient particulate concentrations of gravitational settling and dry deposition that are earlier versions of the more generalized gravitational settling/dry deposition algorithms contained in the ISCST/ISCLT computer codes of the Industrial Source Complex (ISC) Dispersion Model (EPA Reports EPA-450/4-79-030 and 031, December 1979). We replaced the original gravitational settling/dry deposition algorithms contained in the SHORTZ/LONGZ computer codes with the corresponding algorithms contained in the ISCST/ISCLT computer codes for use in calculating the concentrations attributable to the particulate emissions from the IGS with appreciable gravitational settling velocities. The meteorological inputs to the SHORTZ/ LONGZ models were developed from 1949 through 1954 Delta Airport hourly surface weather observations and 1960 through 1964 Salt Lake City mixing depth statistics following techniques previously established for use with the SHORTZ/LONGZ models. The source inputs used in the dispersion model calculations were developed from information provided by IPP and IPP's consultant, Engineering-Science, Inc.

RESULTS OF THE CALCULATIONS

Table I gives the magnitudes and locations of the calculated maximum short-term and annual average ground-level SO_2, particulate and NO_2 concentrations attributable to emissions from the IGS. Table I shows that the maximum short-term and annual average SO_2 and NO_2 concentrations, which are entirely determined by emissions from the single IGS stack, are

TABLE I

MAGNITUDES AND LOCATIONS OF CALCULATED MAXIMUM SHORT-TERM AND ANNUAL AVERAGE GROUND-LEVEL SO_2, PARTICULATE AND NO_2 CONCENTRATIONS ATTRIBUTABLE TO EMISSIONS FROM THE IGS

Pollutant	Averaging Time	Concentration ($\mu g/m^3$)	Location*	
			Distance (km)	Azimuth Bearing (deg)
SO_2	3 Hours 24 Hours Annual	80 32 1.0	6.7 4.0 7.1	023 023 023
Particulates	24 Hours Annual	21 7.5	3.4 3.5	331 328
NO_2	Annual	4.3	7.1	023

* Locations are with respect to the IGS stack.

calculated to occur between 4 and 7 kilometers north-northeast of the stack. On the other hand, the maximum 24-hour and annual average particulate concentrations calculated for the combined emissions from the stack and the low-level sources occur at the boundary of the IGS property and are almost entirely determined by the low-level emissions. For example, the calculated maximum annual average particulate concentration is located at the northern boundary of the IGS property. Emissions assumed to be generated by the hauling and burial of solid waste account for over 80 percent of the calculated maximum annual average concentration.

The area surrounding the IGS plant site is a Class II PSD area. Table II lists the NAAQS for SO_2, particulates and NO_2 and the Class II PSD Increments for SO_2 and particulates. (No PSD Increments have been established for pollutants other than SO_2 and particulates.) The calculated maximum ground-level SO_2 and particulate concentrations from Table I are expressed as percentages of the corresponding Class II PSD Increments in Table III. Depending on the pollutant and the concentration averaging time, emissions from the IGS are calculated to account for 5 to 57 percent of the Class II PSD Increments. The most restrictive Class II Increment is the 24-hour Class II Increment for particulates. We point out that the probability of experiencing the calculated maximum 24-hour average particulate concentration is small because the calculated concentration is based on the assumption that the maximum 24-hour particulate emissions possible during the lifetime of the IGS will coincide in time with the "worst-case" dispersion conditions found in a 6-year period. It is also important to note that the calculated particulate concentrations decrease rapidly with distance from the IGS property boundary.

Comparison of Tables I and II shows that the calculated maximum ground-level concentrations are far below the corresponding NAAQS. However, in assessing the compliance of the IGS with the NAAQS, it is necessary to consider the combined effects of emissions from the IGS, emissions from other major pollutant sources and the background pollutant concentrations. There are no major SO_2, particulate or NO_2 sources in the vicinity of the IGS plant site. In the absence of onsite air quality data, we used

TABLE II

NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS) AND PREVENTION OF SIGNIFICANT DETERIORATION (PSD) INCREMENTS FOR CLASS II AREAS

Pollutant	Averaging Time	NAAQS ($\mu g/m^3$)		Class II PSD Increment ($\mu g/m^3$)
		Primary	Secondary	
SO_2	3 Hours	-	1,300	512
	24 Hours	365	-	91
	Annual	80	-	20
Particulates	24 Hours	260	150	37
	Annual*	75	60	19
NO_2	Annual	100	-	-

*Annual geometric mean.

TABLE III

CALCULATED MAXIMUM SHORT-TERM AND ANNUAL AVERAGE GROUND-LEVEL SO_2 AND PARTICULATE CONCENTRATIONS EXPRESSED AS PERCENTAGES OF THE CORRESPONDING CLASS II PSD INCREMENTS

Pollutant	Averaging Time	Maximum Concentration (% of Class II PSD Increment)
SO_2	3 Hours	15.6
	24 Hours	35.2
	Annual	5.0
Particulates	24 Hours	56.8
	Annual	39.5

the 1982 air quality data available from the UBAQ to estimate the existing air quality in the vicinity of the IGS plant site (see Section 1.3 in the main body of the text). Because the UBAQ air quality monitoring network is principally designed to measure air quality in urban and industrialized areas and major cities, we selected the 1982 air quality measurements from "semi-rural" locations in Utah that we consider most likely to be representative of the existing air quality at the IGS plant site. Table IV gives the annual average and maximum short-term pollutant concentrations that we estimate for the IGS plant site on the basis of the 1982 air quality data. The maximum 3-hour average SO_2 concentration observed in Logan of 26 micrograms per cubic meter approximately corresponds to the threshold concentration of the SO_2 monitor. The maximum 24-hour average SO_2 concentration and the annual average SO_2 concentrations were below the monitor's threshold concentration. The maximum 24-hour average particulate concentration measured at Cedar City of 103 micrograms per cubic meter is about 69 percent of the 24-hour secondary NAAQS, while the annual geometric mean particulate concentration of 39 micrograms per cubic meter is 65 percent of the annual secondary NAAQS. The annual average NO_2 concentration measured at Ogden of 38 micrograms per cubic meter is 38 percent of the NAAQS. We point out that this annual NO_2 concentration is a very safe-sided estimate of the annual NO_2 concentration at the IGS plant site because it reflects the effects of emissions from stationary and mobile sources along the Wasatch Front. In reality, the annual average NO_2 concentration at the IGS plant site is likely to be lower than this concentration by about a factor of 10. If the maximum background concentrations in Table IV are added to the maximum ground-level concentrations calculated for emissions from the IGS, the resulting concentrations are below the corresponding primary and secondary NAAQS.

IDENTIFICATION OF THE UNCERTAINTIES IN THE MODEL CALCULATION

The principle areas of uncertainty affecting the accuracy of the results of the dispersion model calculations presented above are the representativeness of the source input parameters, the representativeness of the meteorological input parameters and the accuracy of the SHORTZ/LONGZ dispersion models. We assume that the source input parameters used in the

TABLE IV

1982 OBSERVED ANNUAL AND MAXIMUM SHORT-TERM SO_2, PARTICULATE AND NO_2 CONCENTRATIONS AT "SEMI-RURAL" LOCATIONS IN UTAH MOST LIKELY TO BE REPRESENTATIVE OF EXISTING AIR QUALITY AT THE IGS PLANT SITE*

Pollutant	Location	Averaging Time	Concentration ($\mu g/m^3$)
SO_2	Logan	3 Hours 24 Hours Annual	26 0 0
Particulates	Cedar City	24 Hours Annual**	103 39
NO_2	Ogden	Annual	38

* Source: Utah Bureau of Air Quality.

** Annual geometric mean.

model calculations, which were developed from information provided by IPP and Engineering-Science, Inc., are representative. We point out that the probability that our assumption that "worst-case" short-term emissions and meteorological conditions will coincide in time is small. The hourly surface weather observations from the nearby Delta, Utah Airport for the 6-year period 1949 through 1954 form a data base that is unusually comprehensive for a remote location. The other meteorological inputs used in the model calculations are based on measurements at similar locations and are believed to be representative of conditions at the IGS plant site.

In studies conducted for EPA by the H. E. Cramer Company, the SHORTZ/LONGZ models have yielded a close correspondence between calculated and observed concentrations for SO_2 sources located in complex terrain at distances up to about 30 kilometers from the source. In a recent performance evaluation of five complex terrain dispersion models that used data collected in the vicinity of a paper mill located in extremely complex terrain, the SHORTZ model was the only model to provide accurate and unbiased estimates of the 25 highest 1-hour, 3-hour and 24-hour average SO_2 concentrations at all monitoring sites at and beyond the distance to plume stabilization, including the sites with both the highest and lowest elevations above the stack-top elevation (H. E. Cramer Company, Inc., Technical Report (draft) TR-83-153-01, March 1983). At the monitoring sites on elevated terrain within the distance to plume stabilization, the SHORTZ model showed a systematic bias toward overestimation. If it is assumed that this bias is a general one, it does not affect the accuracy of the SHORTZ model when applied to the IGS because no significant elevated terrain features are located within the approximate 2-kilometer distance to plume stabilization. The accuracy of the gravitational settling/dry deposition algorithms as applied to the low-level particulate sources at the IGS is difficult to quantify because there have been relatively few verification studies of these algorithms. Perhaps the most rigorous tests of these algorithms are the comparisons of concurrent calculated and observed 24-hour and long-term average particulate concentrations in the vicinity of a large steel mill that were performed using the ISCST/ISCLT computer programs of the ISC Model (see EPA Report EPA-450/4-82-006, February 1982). On the average, the observed concentrations were overpredicted by as much as 20 percent, although uncertainties in the adjustments of the observed concentrations for background may have contributed to the apparent bias toward overestimation.

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SECTION 1
INTRODUCTION

1.1 BACKGROUND AND PURPOSE

The Intermountain Power Project (IPP), a consortium of California, Utah and Nevada utilities, has received approval from the Utah Bureau of Air Quality (UBAQ), the U. S. Environmental Protection Agency (EPA) Region VIII and the U. S. Department of the Interior to construct the 3,000-megawatt coal-fired Intermountain Generating Station (IGS) at the Lynndyl site near Delta, Utah. The approval by these agencies of the construction and operation of the IGS was in part based on a dispersion model analysis of the air quality impact of stack emissions from the IGS that was performed by the H. E. Cramer Company, Inc. (Bowers, et al., August 1978). This August 1978 air quality impact analysis was subsequently updated to reflect slight changes in stack configuration (Bowers, et al., June 1981). Both of these analyses indicated that the IGS would comply with the National Ambient Air Quality Standards (NAAQS) and the Prevention of Significant Deterioration (PSD) Increments.

IPP has recently notified the UBAQ of design refinements and a reduction in project size from four to two generating units. In order to evaluate the effects on ambient air quality of these changes, IPP has requested that the H. E. Cramer Company repeat the dispersion model calculations described in the August 1978 and June 1981 reports using the current plant configuration and parameters, including a maximum boiler heat input of 8,352 million British Thermal Units (BTU) per hour. Additionally, because detailed engineering estimates of low-level particulate emissions from operations such as coal handling and haul road traffic are now available, IPP has requested that the air quality impact of these emissions also be considered in the dispersion model calculations.

The purpose of this report is to provide IPP with the results of dispersion model calculations of the air quality impact of emissions from the present two-unit configuration for the IGS. The specific calculations described in this report are as follows:

- Maximum annual average ground-level concentrations of sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and particulates

- Maximum 24-hour average ground-level concentrations of SO_2 and particulates

- Maximum 3-hour average ground-level SO_2 concentration

The results of these calculations are presented and compared with the NAAQS and the PSD Increments for Class II (moderate growth) areas.

1.2 DESCRIPTION OF THE SITE

Figure 1-1 is a topographic map of the area surrounding the IGS plant site. Elevations in the figure are in feet above mean sea level (MSL) and the contour interval is 1,000 feet (305 meters). The IGS plant site is located approximately 18 kilometers north of Delta, Utah at an elevation of 1,425 meters MSL. As shown by Figure 1-1, the site is near the center of a broad valley which has a north-northeast to south-southwest orientation. The mountains forming the east side of the valley rise to over 2,700 meters MSL and the mountains forming the west side of the valley rise to over 2,400 meters MSL. As discussed in Section 2.2, this deep valley has a well-defined valley wind regime; the most frequent wind directions are parallel to the axis of the valley and cross-valley winds are rare. This type of wind circulation is characteristic of Utah valleys. The valley floor is relatively flat except for isolated terrain features such as Fumarole Butte, 22 kilometers northwest of the IGS plant site, which rises to an elevation 200 meters above plant grade.

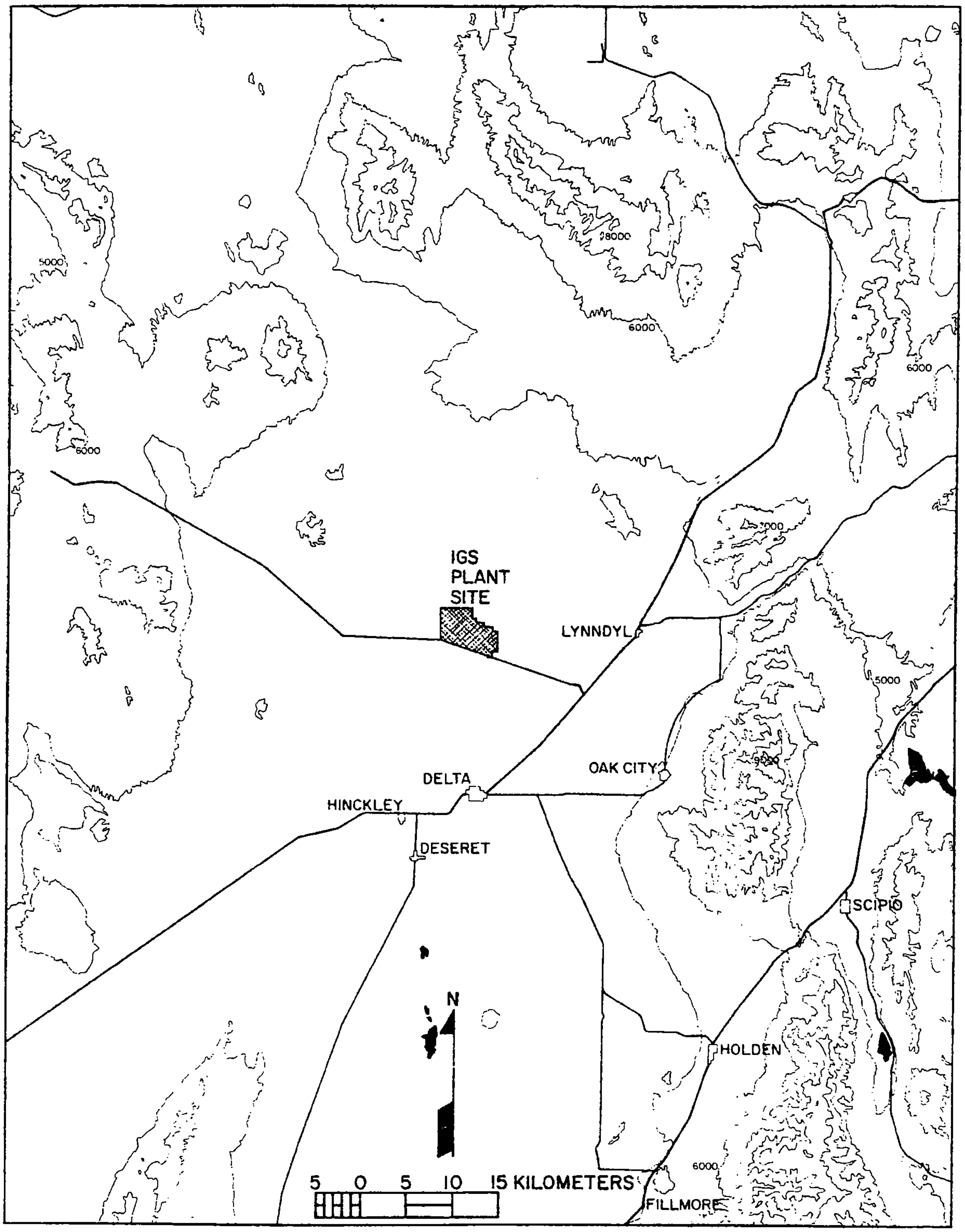

FIGURE 1-1. Topographic map of the area surrounding the IGS plant site. Elevations are in feet above mean sea level, and the contour interval is 1,000 feet (305 meters).

1.3 EXISTING AIR QUALITY

To the best of our knowledge, no valid air quality data currently are available for the area in the vicinity of the IGS plant site. The major stationary pollutant sources nearest to the site are a copper smelter located approximately 140 kilometers to the north-northeast and a steel works located approximately 115 kilometers to the northeast. During periods of north winds, emissions from the smelter are transported along either the east or west side of the Oquirrh Mountains. Emissions that travel to the southwest enter the Rush Valley air basin, which is bounded on the south by the Sheep Rock and Tintic Mountains and on the west by the Stansbury Mountains. Similarly, the steel works is separated from the air basin containing the IGS plant site by the Tintic Mountains. Although there are some interactions at the boundaries of adjacent air basins, we believe that high dilution conditions (moderate-to-strong winds and deep surface mixing layers) are required for the occurrence of a significant exchange between air basins. Consequently, it is unlikely that emissions from the copper smelter, the steel works and other pollutant sources along the Wasatch Front significantly affect the existing ambient air quality in the vicinity of the IGS plant site. We therefore conclude that the existing air quality in the vicinity of the IGS plant site is likely to be typical of the air quality at other locations in rural Utah.

We obtained from the UBAQ a summary of the 1982 air quality measurements from the Utah Division of Health's air quality monitoring network. This network is principally designed to measure air quality in urban and industrialized areas and major cities. We therefore selected the 1982 measurements for SO_2 and particulates from the "semi-rural" monitoring sites in Utah that we consider most likely to be representative of the existing air quality at the ICS plant site. The Utah Division of Health's air quality monitoring network does not include any "semi-rural" NO_2 monitoring sites. We therefore selected Ogden, which is affected by emissions from stationary and mobile sources along the Wasatch Front, as the closest approximation to a "semi-rural" NO_2 monitoring site. Table 1-1 gives the annual average and maximum short-term pollutant concentrations that we estimate for the IGS plant site on the basis of the 1982 air quality data. The maximum 3-hour average SO_2 concentration observed in Logan of 26 micrograms per cubic meter approximately corresponds to the threshold concentration of the SO_2 monitor. For comparison, the annual NAAQS for SO_2 is 80 micrograms per cubic meter. The maximum 24-hour average SO_2 concentration and the annual average SO_2 concentration were below the monitor's threshold concentration. The maximum 24-hour average particulate concentration measured at Cedar City of 103 micrograms per cubic meter is about 69 percent of the 24-hour secondary NAAQS, while the annual geometric mean particulate concentration of 39 micrograms per cubic meter is about 65 percent of the annual secondary NAAQS. The 1982 annual average NO_2 concentration at Ogden of 38 micrograms per cubic meter is 38 percent of the annual NAAQS. Based on the historical NO_2 air quality data for rural Utah summarized by Collins, et al. (1980), this annual average NO_2 concentration is probably about a factor of 10 higher than the annual average NO_2 concentration at the IGS plant site.

In summary, Table 1-2 gives the NAAQS and the annual average and maximum short-term pollutant concentrations estimated for the IGS plant site using 1982 data from "semi-rural" locations in Utah. Because no 1982 NO_2 air quality data are available for a "semi-rural" location in Utah, the annual average NO_2 concentration in Table 1-2 is from an urban monitoring site believed to have an annual NO_2 concentration that is about a factor of 10 higher than the NO_2 concentration in the vicinity of the IGS plant site. Table 1-2 shows that the existing air quality in "semi-rural" and rural Utah is very good. The only estimated background concentrations that account for as much as 50 percent of the corresponding NAAQS are the 24-hour and annual average particulate concentrations. Hill, et al. (1976) analyzed high-volume (hi-vol) filter samples for the days with the highest observed particulate concentrations in the Castle Valley (Emery County, Utah) and found wind-blown soil dust to be the primary constituent. Thus, the background particulate concentrations probably are determined by the

TABLE 1-1

1982 OBSERVED ANNUAL AND MAXIMUM SHORT-TERM SO_2, PARTICULATE AND NO_2 CONCENTRATIONS AT "SEMI-RURAL" LOCATIONS IN UTAH MOST LIKELY TO BE REPRESENTATIVE OF EXISTING AIR QUALITY AT THE IGS PLANT SITE*

Pollutant	Location	Averaging Time	Concentration ($\mu g/m^3$)
SO_2	Logan	3 Hours 24 Hours Annual	26 0 0
Particulates	Cedar City	24 Hours Annual**	103 39
NO_2	Ogden	Annual	38

* Source: Utah Bureau of Air Quality.

** Annual geometric mean.

TABLE 1-2

NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS) AND ESTIMATED EXISTING ANNUAL AVERAGE AND MAXIMUM SHORT-TERM POLLUTANT CONCENTRATIONS IN THE VICINITY OF THE IGS PLANT SITE

Pollutant	Averaging Time	NAAQS ($\mu g/m^3$)		Estimated Maximum Concentration ($\mu g/m^3$)
		Primary	Secondary	
SO_2	3 Hours	-	1,300	26
	24 Hours	365	-	0
	Annual	80	-	0
Particulates	24 Hours	260	150	103
	Annual*	75	60	39
NO_2	Annual	100	-	38

* Annual geometric mean.

natural background and localized activities such as agriculture, cattle grazing and transportation.

1.4 SELECTION OF DISPERSION MODELS

As shown by Figure 1-1, terrain elevations above the 216-meter IGS stack-top elevation occur within a 30-kilometer radius of the stack. Thus, complex terrain dispersion modeling techniques are required to assess the air quality impact of the stack emissions. For this reason, all previous dispersion model analyses that the H. E. Cramer Company has performed for the IGS have used the SHORTZ/LONGZ complex terrain dispersion models. We consider the SHORTZ/LONGZ models, which were developed and documented by the H. E. Cramer Company under contract to the U. S. Environmental Protection Agency (Cramer, et al., 1975; Bjorklund and Bowers, 1982), to be the most refined (non-screening) complex terrain dispersion models currently available. As discussed in Appendix H of the report by Bjorklund and Bowers (1982), the SHORTZ/LONGZ models have performed well in studies during the last 8 years that have included direct comparisons of calculated and observed SO_2 concentrations for existing sources located in complex terrain. Under contract to EPA, we have just completed the most rigorous test to date of the SHORTZ model using the emissions, meteorological and SO_2 air quality data collected during a 2-year monitoring program in the vicinity of the Westvaco Corporation Luke, Maryland Mill. As discussed by Bowers, et al. (1983), the SHORTZ model closely matched the 25 highest observed 1-hour, 3-hour and 24-hour average SO_2 concentrations at all monitoring sites at and beyond the typical distance to plume stabilization, including the sites with the lowest and highest elevations above the stack-top elevation. At the monitoring sites on elevated terrain within the distance to plume stabilization, the SHORTZ model consistently overestimated the 25 highest observed short-term concentrations. Because the elevated terrain in the vicinity of the IGS plant site is beyond the approximate 2-kilometer distance to plume stabilization, the results of the Westvaco study support the continued use of the SHORTZ/LONGZ models as refined complex terrain dispersion models for the IGS at the Lynndyl site.

The SHORTZ/LONGZ models contain the features and options required to model the air quality impact of the low-level particulate emissions associated with activities such as coal and lime/limestone handling at the IGS. These features include the option to account for the effects on ambient particulate concentrations of gravitational settling and dry deposition for particulates with appreciable gravitational settling velocities under the assumption that all particulates that reach the surface by the combined processes of atmospheric turbulence and gravitational settling are retained (deposited) at the surface. The ISCST and ISCLT computer codes of the Industrial Source Complex (ISC) Dispersion Model (Bowers, et al., 1979) use a more generalized form of this gravitational settling/dry deposition algorithm in which the smaller particulates are partially or completely reflected at the ground surface, depending on their terminal fall velocities. We replaced the gravitational settling/dry deposition algorithms contained in the original SHORTZ and LONGZ computer codes with the corresponding gravitational settling/dry deposition algorithms contained in the ISCST and ISCLT computer codes (see Equations (2-40) and (2-51) in the ISC Model User's Guide) for use in the particulate concentration calculations described in this report for emissions from the low-level sources at the IGS.

1.5 REPORT ORGANIZATION

In addition to the Introduction, this report contains three major sections and two appendices. Section 2 discusses the source and meteorological inputs used in the SHORTZ/LONGZ dispersion model calculations. Section 3 gives the calculation procedures and results and compares the calculated maximum ground-level concentrations with the corresponding NAAQS and Class II PSD Increments. The major areas of uncertainty in the model calculations are identified in Section 4. Appendix A discusses the determination of the maximum combined emissions from the solid waste soil stockpile and the solid waste burial pile. The hourly meteorological inputs used in the SHORTZ model calculations are listed in Appendix B.

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SECTION 2

SOURCE AND METEOROLOGICAL INPUT PARAMETERS

2.1 SOURCE INPUT PARAMETERS

The IGS will consist of two coal-fired electric generating units. The IGS's single 216-meter stack will have two inner flues with diameters of 8.54 meters. For modeling purposes, these inner flues result in an effective stack diameter of 12.1 meters. A major advantage of the two-flue design is that the stack exit velocity is not decreased when only one unit is in operation. That is, the two-flue stack design reduces the possibility that stack-tip and/or building downwash will decrease buoyant plume rise during periods of moderate or strong winds.

The stack and "worst-case" emissions parameters for the IGS, which were developed from information provided by IPP, are listed in Table 2-1. With the exception of the annual average pollutant emission rates, the emissions parameters in Table 2-1 are for plant operation at maximum possible load. According to IPP, the maximum annual generation of the IGS will be 85 percent of the maximum possible generation, which corresponds to a boiler heat input of 8,352 million BTU per hour. Consequently, the annual average pollutant emission rates in Table 2-1 are 85 percent of the corresponding maximum short-term emission rates. The NO_2 emission rate assumes that 100 percent of the nitric oxide (NO) molecules in the plume are immediately converted to NO_2. In reality, only about 10 percent of the NO_x (NO plus NO_2) molecules are initially in the form of NO_2 (see Cole and Summerhays, 1979).

The source inputs for the low-level particulate sources at the IGS were developed from information contained in the 2 May 1983 report "Quantification of the Fugitive Emissions at the Intermountain Generating Station (IGS) (Two Unit Scenario)," which was prepared for IPP by

TABLE 2-1

STACK PARAMETERS AND WORST-CASE EMISSIONS DATA FOR THE IGS

Stack Parameter	Parameter Value
Stack Height (m)	216
Stack Inner Diameter (m)	12.1*
UTM X Coordinate (m)	364,225
UTM Y Coordinate (m)	4,374,462
Stack Base Elevation (m above MSL)	1,425
Volumetric Emission Rate (m^3/sec)	2,472
Stack Exit Velocity (m/sec)	21.6
Stack Exit Temperature (°K)	330
SO_2 Emission Rate (g/sec)	
Maximum Short-Term	316
Annual Average	268
Particulate Emission Rate (g/sec)**	
Maximum Short-Term	42.2
Annual Average	35.8
Annual Average NO_2 Emission Rate (g/sec)***	1,157.6

* Effective diameter for two inner flues with diameters of 8.54 meters.

** The particulate emission rates assume that 20 percent of the flyash is contained in the bottom ash and that 80 percent is contained in the flue gas.

*** The NO_2 emission rate assumes that 100 percent of the NO molecules in the plume are immediately converted to NO_2.

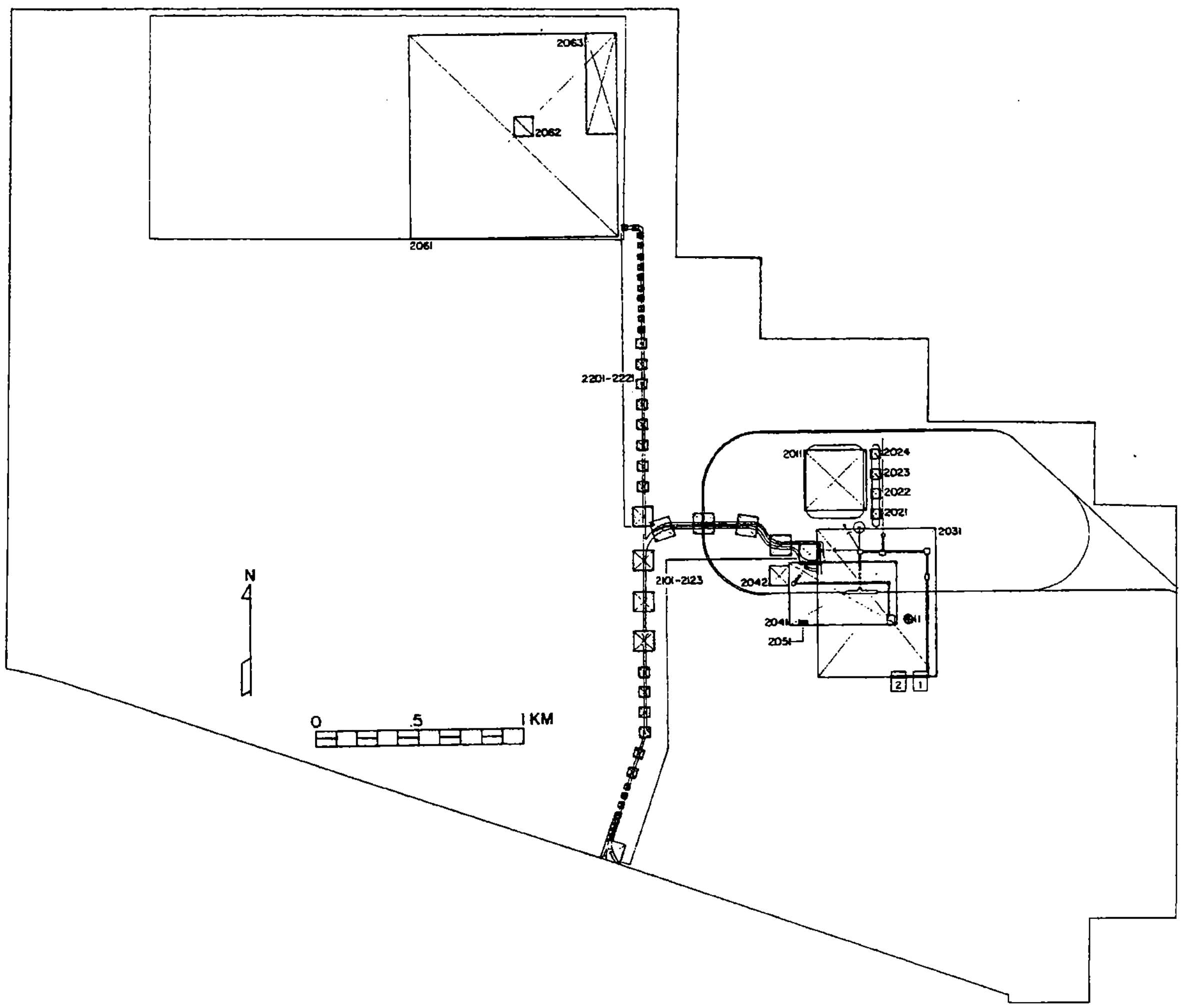

FIGURE 2-1. Layout of the IGS showing the locations of the particulate sources used in the dispersion model calculations. See Table 2-2 for an identification of the source numbers used in this figure. The rectangles numbered "1" and "2" in this figure are the buildings that contain the two boilers.

Engineering-Science, Inc. Figure 2-1 shows the locations of the particulate sources used in the dispersion model calculations and Table 2-2 relates the source identification numbers used in Figure 2-1 to the various sources at the IGS. Table 2-3 gives all of the source input parameters for the low-level sources except the particulate emission rates, which are given in Table 2-4. For modeling purposes, the storage piles are represented in Table 2-3 as area sources (SHORTZ/LONGZ Source Type 2) with horizontal dimensions approximately equal to the expected horizontal dimensions and characteristic height scales equal to the expected heights. Emissions from the coal and limestone handling activities are accounted for by two large area sources with horizontal dimensions that approximately correspond to the dimensions of the areas within which these activities will take place and characteristic height scales approximately equal to the average heights of the coal and limestone conveyor systems. These area sources also include the emissions arising from the unloading of trucks and railroad cars as well as from the conveying, transfer and crushing of materials. Emissions from flyash handling activities are represented in Table 2-3 by a building source (SHORTZ/LONGZ Source Type 1) with horizontal and vertical dimensions approximately equal to the dimensions of the flyash processing building. This building source also includes the emissions from flyash silo unloading, the flyash silo vent and the pug mill vent.

Emissions from the roadways within the IGS property effectively form line sources. An exact representation of these line sources can be obtained by using a series of adjacent square area sources with sides equal to the widths of the corresponding roadways. However, because the majority of the roadways are located well within the IGS property, the roadway emissions can be represented by a smaller number of area sources without any significant loss of accuracy in the concentrations calculated at the boundary of the IGS property. Based on our previous experience in modeling line sources (for example, see Bowers, et al., 1979), we selected the dimensions of the area sources used to represent the coal and limestone haul road and the solid waste disposal area access road as follows:

TABLE 2-2

SOURCE IDENTIFICATION NUMBERS FOR THE PARTICULATE SOURCES AT THE IGS

Source Identification Number(s)	Source
11	Main Stack
2011	Reserve Coal Storage Pile
2021-2024	Active Coal Storage Pile
2031	Coal Handling
2041	Limestone Handling
2042	Reserve and Active Limestone Storage Pile
2051	Flyash Handling
2061	Solid Waste Hauling and Burial of Solid Waste
2062	Solid Waste Soil Stockpile
2063	Solid Waste Burial Pile
2101-2123	Coal and Limestone Haul Road
2201-2221	Solid Waste Disposal Area Access Road

TABLE 2-3
SOURCE INPUTS OTHER THAN PARTICULATE EMISSION RATES
FOR THE LOW LEVEL PARTICULATE SOURCES AT THE IGS

SOURCE NUMBER	T* Y P E	UTM X (METERS)	UTM Y (METERS)	HEIGHT OF EMISSIONS (METERS)	SOURCE WIDTH (METERS)	SOURCE LENGTH (METERS)
2011	2	363880	4375145	12.2	300.0	300.0
2021	2	364075	4374975	18.3	50.0	50.0
2022	2	364075	4375075	18.3	50.0	50.0
2023	2	364075	4375175	18.3	50.0	50.0
2024	2	364075	4375275	18.3	50.0	50.0
2031	2	364075	4374540	20.0	600.0	750.0
2041	2	363910	4374585	10.0	300.0	550.0
2042	2	363600	4374675	12.2	100.0	100.0
2051	1	363720	4374445	30.0	30.0	40.0
2061	2	362335	4376845	2.0	1000.	1000.
2062	2	362385	4376895	5.0	100.0	100.0
2063	2	362760	4377095	12.2	150.0	500.0
2101	2	363750	4374785	2.0	100.0	100.0
2102	2	363610	4374825	2.0	100.0	100.0
2103	2	363455	4374920	2.0	100.0	100.0
2104	2	363255	4374935	2.0	100.0	100.0
2105	2	363055	4374915	2.0	100.0	100.0
2106	2	362950	4374760	2.0	100.0	100.0
2107	2	362950	4374560	2.0	100.0	100.0
2108	2	362950	4374360	2.0	100.0	100.0
2109	2	362950	4374210	2.0	50.0	50.0
2110	2	362950	4374110	2.0	50.0	50.0
2111	2	362950	4374010	2.0	50.0	50.0
2112	2	362950	4373910	2.0	50.0	50.0
2113	2	362920	4373815	2.0	50.0	50.0
2114	2	362887	4373721	2.0	50.0	50.0
2115	2	362863	4373650	2.0	25.0	25.0
2116	2	362847	4373603	2.0	25.0	25.0
2117	2	362830	4373555	2.0	25.0	25.0
2118	2	362814	4373503	2.0	25.0	25.0
2119	2	362802	4373473	2.0	25.0	25.0
2120	2	362794	4373449	2.0	25.0	25.0
2121	2	362786	4373425	2.0	25.0	25.0
2122	2	362778	4373402	2.0	25.0	25.0
2123	2	362793	4373330	2.0	100.0	100.0
2201	2	362935	4374990	2.0	100.0	100.0
2202	2	362935	4375140	2.0	50.0	50.0

TABLE 2-3 (CONTINUED)

SOURCE NUMBER	T* Y P E	UTM X (METERS)	UTM Y (METERS)	HEIGHT OF EMISSIONS (METERS)	SOURCE WIDTH (METERS)	SOURCE LENGTH (METERS)
2203	2	362935	4375240	2.0	50.0	50.0
2204	2	362935	4375340	2.0	50.0	50.0
2205	2	362935	4375440	2.0	50.0	50.0
2206	2	362935	4375540	2.0	50.0	50.0
2207	2	362935	4375640	2.0	50.0	50.0
2208	2	362935	4375740	2.0	50.0	50.0
2209	2	362935	4375840	2.0	50.0	50.0
2210	2	362935	4375915	2.0	25.0	25.0
2211	2	362935	4375965	2.0	25.0	25.0
2212	2	362935	4376015	2.0	25.0	25.0
2213	2	362935	4376065	2.0	25.0	25.0
2214	2	362935	4376115	2.0	25.0	25.0
2215	2	362935	4376165	2.0	25.0	25.0
2216	2	362935	4376215	2.0	25.0	25.0
2217	2	362935	4376265	2.0	25.0	25.0
2218	2	362935	4376315	2.0	25.0	25.0
2219	2	362935	4376365	2.0	25.0	25.0
2220	2	362910	4376410	2.0	25.0	25.0
2221	2	362860	4376410	2.0	25.0	25.0

* TYPE 1 IS A BUILDING SOURCE. TYPE 2 IS AN AREA SOURCE.

TABLE 2-4

PARTICULATE EMISSION RATES FOR THE LOW-LEVEL SOURCES AT THE IGS

Source Number(s)	Emission Rate (g/sec)	
	Annual Average	Maximum 24-Hour
2011	0.597*	0.739**
2021-2024 (each)	0.490*	0.715**
2031	0.518	0.624
2041	0.0218	0.0256
2042	0.0851*	0.117**
2051	0.185	0.236
2061	0.613	1.21
2062	0.164*	-
"Strong Wind" 24-Hour Cases	-	0.406**
"Light Wind" 24-Hour Cases	-	0.114**
2063	0.0423	-
"Strong Wind" 24-Hour Cases	-	0
"Light Wind" 24-Hour Cases	-	0.0643
2101-2108 (each)	0.0391	0.0460
2109-2114 (each)	0.0195	0.0230
2115-2118 (each)	0.00977	0.0115
2119-2122 (each)	0.00488	0.00575
2123	0.0195	0.0230
2201	0.01287	0.01900
2202-2209	0.00644	0.00950
2210-2221	0.00322	0.00475

* Emission rate for the highest three wind-speed categories (wind speeds greater than or equal to 5.2 meters per second); the emission rate for the lowest three categories (wind speeds less than or equal to 5.1 meters per second) is zero.

** Emission rate for hours when the mean wind speed is greater than or equal to 5.4 meters per second; the emission rate for hours when the wind speed is less than 5.4 meters per second is zero.

(1) For roadway segments within 200 meters of the IGS property boundary, each 25 meters of roadway was represented by a 25-meter square area source

(2) For roadway segments between 200 and 400 meters of the property boundary, each 50 meters of roadway was represented by a 25-meter square area source centered on the roadway segment

(3) For roadway segments between 400 and 900 meters from the property boundary, each 100 meters of roadway was represented by a 50-meter square area source centered on the roadway segment

(4) For roadway segments more than 900 meters from the property boundary, each 200 meters of roadway was represented by a 100-meter square area source centered on the roadway segment

To account for the effects of the mechanical turbulence generated by the haul road traffic and the heated exhaust, the characteristic height scale of the roadway segments was set equal to 2 meters, which is consistent with the semi-empirical assumptions of the HIWAY-2 model (Petersen, 1980). Because the location of the solid waste haul road will vary throughout the lifetime of the IGS, a single area source with horizontal dimensions approximately defined by all of the possible locations of the solid waste haul road was used in the model calculations. Emissions generated by the solid waste burial process are included in the total emissions from this area source.

We used annual average particulate emission rates in the LONGZ model calculations of annual average particulate concentrations and the maximum possible short-term particulate emission rates in the SHORTZ model calculations of 24-hour average particulate concentrations. Based on the information provided by Engineering-Science, Inc. (1983), emissions from storage piles will occur only when the wind speed exceeds 5.4 meters per second (12 miles per hour). This wind-speed dependence was automatically accounted for in the SHORTZ/LONGZ model calculations by using the model option that allows different emission rates to be assigned to various wind-speed categories (see Table 2-4).

The particulate emission rates for most of the sources at the IGS may be considered for modeling purposes to be approximately constant. However, the steady-state assumption is not appropriate for emissions from the solid waste soil stockpile and the solid waste burial pile. The area of the soil stockpile and hence the emissions from the stockpile will be at a maximum at the start of operation of the IGS. During the first 2.5 years of operations, soil will be removed from the stockpile and spread over the solid waste to form the solid waste burial pile. When the initial soil stockpile is fully depleted after 2.5 years, the soil from new waste disposal excavations will be used to cover the solid waste. After the soil is deposited over the solid waste, it will be compacted, seeded and watered. The "control efficiency" achieved is expected initially to be 50 percent. However, the soil surface is expected gradually to stabilize and return to a nearly natural state (100 percent "control efficiency") during a reclamation period of about 2.5 years. Therefore, after the first 2.5 years, new soil will be added to the solid waste burial pile at about the same rate that soil previously used to cover solid waste is returned to a nearly natural state, and the emission rate will have reached a steady state. To summarize, the area of the soil stockpile will decrease from its maximum value to zero during the first 2.5 years of operation, while the area of disturbed soil used to bury the solid waste will increase from zero to its maximum and final value. Over the same period, the "control efficiency" for emissions from the soil covering the solid waste will increase from 50 percent at the start of operation to an areal average at 2.5 years of 75 percent (ranging from 50 percent for freshly covered solid waste to nearly 100 percent for solid waste covered at the start of operation). The maximum combined emission rate for these two sources, which will occur during the initial 2.5-year period of operation, is in part a function of the percent frequency of occurrence of wind speeds greater than 5.4 meters per second during the period. Appendix A discusses in detail the determination of the maximum possible combined emissions from the soil stockpile and the solid waste burial pile.

The particulate emissions from the IGS stack and from the flyash handling activities have diameters and terminal fall velocities sufficiently small that they can be assumed to be transported and dispersed in the same manner as gases. However, the particulate emissions from the other sources at the IGS have diameters and terminal fall velocities sufficiently large that the effects of gravitational settling and dry deposition should be included in the dispersion model calculations. Based on the particulate size distributions reported by Engineering-Science, Inc. (1983), Table 2-5 gives the inputs required by the updated gravitational settling/dry deposition algorithms of the SHORTZ/LONGZ models (see Section 1.4). These inputs were developed following the procedures specified by Bowers, et al. (1979) for use with the same algorithms in the Industrial Source Complex (ISC) Dispersion Model assuming a density of 1.5 grams per cubic centimeter for coal dust and 2.5 grams per cubic centimeter for all other dust particles.

Table 2-6 lists the pollutant sources that have been permitted by the UBAQ after the baseline date that was established by the granting of a PSD Permit to the IGS (Dalley, 1982). Because none of these sources is a "major" source for any pollutant (i.e., a source with controlled emissions of any pollutant that exceed 100 tons per year, which is equal to 2.88 grams per second), none of these sources required a PSD Permit. Nevertheless, emissions from these sources must be considered in combination with emissions from the IGS in assessing compliance with the PSD Increments. The information in Table 2-6, which is all of the information readily available for these sources from the files of the UBAQ, is entirely inadequate for dispersion modeling purposes. However, there are several conclusions that can be drawn from Table 2-6. First, the distance from the IGS plant site to each of the sources is probably more than 50 kilometers, the distance beyond which the current PSD Regulations generally do not require the use of dispersion models (Federal Register, Vol. 43, No. 118). Second, the

TABLE 2-5

GRAVITATIONAL SETTLING/DRY DEPOSITION INPUTS FOR THE PARTICULATE SOURCES

Source(s)	Particle Diameter Range (µm)	Mass Fraction in Range	Settling Velocity (m/sec)	Surface Reflection Coefficient
2011 and 2021-2024	15-30	0.38	1.52×10^{-2}	0.74
	10-15	0.15	4.53×10^{-3}	0.86
	0-10	0.47	1.11×10^{-3}	0.94
2031	15-30	0.34	1.52×10^{-2}	0.74
	10-15	0.17	4.53×10^{-3}	0.86
	0-10	0.49	1.11×10^{-3}	0.94
2041	15-30	0.34	2.54×10^{-2}	0.69
	10-15	0.17	7.55×10^{-3}	0.80
	0-10	0.49	1.86×10^{-3}	0.89
2042, 2062 and 2063	15-30	0.38	2.54×10^{-2}	0.69
	10-15	0.15	7.55×10^{-3}	0.80
	0-10	0.47	1.86×10^{-3}	0.89
2061 and 2201-2221	15-30	0.29	2.54×10^{-2}	0.69
	10-15	0.15	7.55×10^{-3}	0.80
	0-10	0.56	1.86×10^{-3}	0.89
2101-2123	15-30	0.28	2.54×10^{-2}	0.69
	10-15	0.16	7.55×10^{-3}	0.80
	0-10	0.56	1.86×10^{-3}	0.89

TABLE 2-6

SOURCES PERMITTED BY THE UBAQ AFTER THE BASELINE DATA ESTABLISHED BY THE IGS

Source	Location	Pollutant Emission Rate (g/sec)		
		SO_2	Particulates	NO_2
Nephi Lumber Company	Juab County	--	0.011	--
Champion, Inc.	Millard County	0.228	0.381	0.037
Acme Concrete	Juab County	0.018*	2.309*	0.197*
Western Rock Products	Juab County	--	0.088	--

* Emission rates assume twelve projects per year.

combined SO_2 and NO_2 emissions from all four sources listed in Table 2-6 are less than 0.1 percent of the corresponding emissions from the IGS, while the combined particulate emissions are less than 6 percent of the particulate emissions from the IGS. We therefore conclude that the contributions (if any) of emissions from the sources listed in Table 2-6 to the maximum ground-level SO_2, particulate and NO_2 concentrations in the vicinity of the IGS will be negligible in comparison with the contributions of emissions from the IGS. Consequently, we did not include the sources in Table 2-6 in the dispersion model calculations described in this report.

2.2 METEOROLOGICAL INPUT PARAMETERS

As discussed in Section 1.4, all previous dispersion model analyses of the air quality impact of emissions from the IGS that have been performed by the H. E. Cramer Company have used the SHORTZ/LONGZ complex terrain dispersion models. Table 2-7 lists the hourly meteorological inputs required by the SHORTZ model and Table 2-8 lists the meteorological inputs required by the LONGZ model. This section discusses the development of the meteorological inputs to the SHORTZ/LONGZ models.

As shown by Figure 1-1, the IGS plant site is located near the center of a broad valley approximately 17 kilometers northwest of the Delta, Utah Airport. No elevated terrain features exist between the site and the Delta Airport. We obtained from the National Climatic Center a computer tape containing the hourly surface weather observations made at the Delta Airport during the 6-year period from January 1949 through December 1954. Figure 2-2 shows the annual wind-direction distribution during this period. The directions in Figure 2-2 are reversed 180 degrees and are the directions toward which the wind is blowing. Reversed wind directions are used in Figure 2-2 because the annual distribution of pollutants emitted from a single source closely resembles the reversed annual wind-direction distribution. In general, the most frequent wind directions at the Delta Airport reflect the approximate north-northeast to south-southwest orientation of

TABLE 2-7

HOURLY METEOROLOGICAL INPUTS REQUIRED BY THE SHORTZ MODEL

Parameter	Definition
$\bar{u}_R$	Mean wind speed (m/sec) at height z_R
DD	Mean wind direction (deg) at height z_R
p	Wind-profile exponent
σ'_A	Wind azimuth-angle standard deviation in radians
σ'_E	Wind elevation-angle standard deviation in radians
T_a	Ambient air temperature (^{o}K)
H_m	Depth of surface mixing layer (m)
$\frac{\partial\theta}{\partial z}$	Vertical potential temperature gradient (^{o}K/m)

TABLE 2-8

TABLES OF METEOROLOGICAL INPUTS REQUIRED BY THE LONGZ MODEL

Parameter	Definition
$f_{i,j,k}$	Frequency distribution of wind-speed and wind-direction categories by stability or time-of-day categories
$\bar{u}\{z_R\}_i$	Mean wind speed (m/sec) at height z_R for the i^{th} wind-speed category
$p_{i,k}$	Wind-profile exponent for the i^{th} wind-speed category and k^{th} stability or time-of-day category
$\sigma'_{E;i,k}$	Standard deviation of the wind-elevation angle in radians for the i^{th} wind-speed category and k^{th} stability or time-of-day category
$T_{a;k}$	Ambient air temperature for the k^{th} stability or time-of-day category
$\left(\frac{\partial\theta}{\partial z}\right)_{i,k}$	Vertical potential temperature gradient for the i^{th} wind-speed category and k^{th} stability or time-of-day category
$H_{m;i,k}$	Median surface mixing depth for the i^{th} wind-speed category and k^{th} stability or time-of-day category

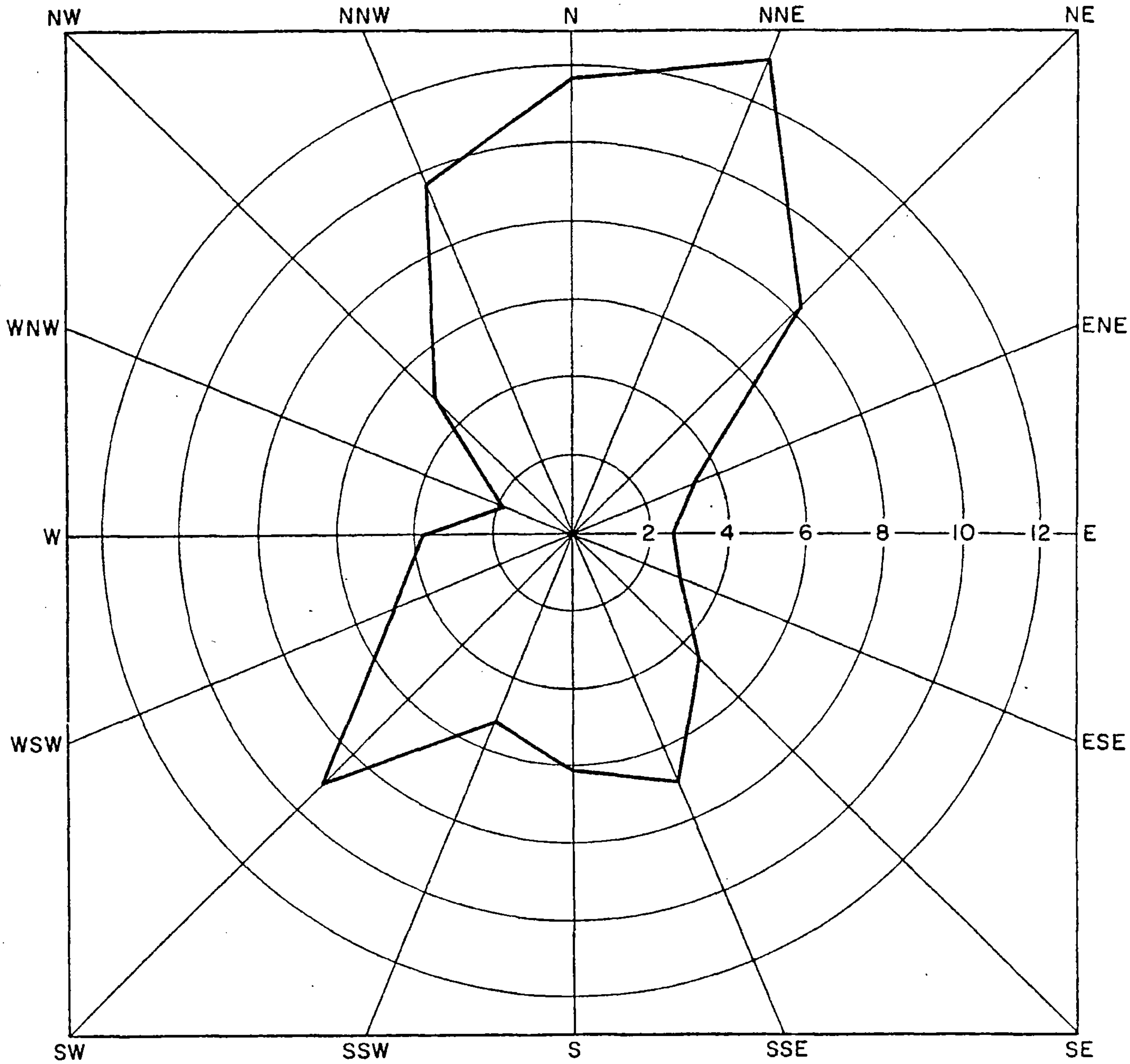

FIGURE 2-2. Annual wind-direction distribution at Delta, Utah during the period 1949-1954. Directions are directions toward which the wind is blowing, and the frequency scale is shown at the right center of the figure.

the valley. Local influences (for example, a shallow layer of nighttime drainage winds from the elevated terrain east of the Delta Airport) are most likely to affect the low-level winds during periods with light winds. However, the most frequent wind directions for light wind speeds at the Delta Airport are also the most frequent wind directions for moderate-to-strong wind speeds. Thus, the Delta Airport wind data do not show any significant local influences that would make the data non-representative of conditions at the plant site. We therefore believe that the meteorological data from the Delta Airport are suitable for use in dispersion model calculations for the IGS.

We used the hourly surface weather observations made at the Delta Airport during the period 1949 through 1954 to generate the annual distribution of wind-speed and wind-direction categories, classified according to the Pasquill stability categories. This distribution was developed using the Turner (1964) definitions of the Pasquill stability categories. Tables 2-9 and 2-10 list the parameters that define the various stability categories. The thermal stratifications represented by the Pasquill stability categories are:

- A - Very unstable
- B - Unstable
- C - Slightly unstable
- D - Neutral
- E - Stable
- F - Very stable

The annual wind summary used in the LONGZ model calculations of annual average concentrations is shown in Table 2-11.

As explained by Bjorklund and Bowers (1982), the SHORTZ/LONGZ models use a wind-profile exponent law to adjust the mean wind speed from the measurement height to the stack height for the plume rise calculations and to the plume stabilization height for the concentration calculations.

TABLE 2-9

PASQUILL STABILITY CATEGORY AS A FUNCTION OF INSOLATION AND WIND SPEED

Wind Speed (Knots)	Insolation Index						
	4	3	2	1	0	-1	-2
0,1	A	A	B	C	D	F	F
2,3	A	B	B	C	D	F	F
4,5	A	B	C	D	D	E	F
6	B	B	C	D	D	E	F
7	B	B	C	D	D	D	E
8,9	B	C	C	D	D	D	E
10	C	C	D	D	D	D	E
11	C	C	D	D	D	D	D
≥ 12	C	D	D	D	D	D	D

TABLE 2-10

INSOLATION CATEGORIES

Insolation	Insolation Category Number
Strong	4
Moderate	3
Slight	2
Weak	1
Overcast < 7,000 feet (day or night)	0
Cloud Cover > 4/10 (night)	-1
Cloud Cover ≤ 4/10 (night)	-2

TABLE 2-11

ANNUAL JOINT FREQUENCY OF OCCURRENCE OF WIND-SPEED AND WIND-DIRECTION CATEGORIES, CLASSIFIED ACCORDING TO THE PASQUILL STABILITY CATEGORIES, AT THE DELTA, UTAH AIRPORT

STABILITY CATEGORY A

DIRECTION (SECTOR)	WIND SPEED (M/SEC) 0-1.5	1.6-3.0	TOTAL
N	.0013	.0002	.0015
NNE	.0010	.0002	.0013
NE	.0011	.0001	.0012
ENE	.0004	.0001	.0004
E	.0005	.0001	.0006
ESE	.0004	.0001	.0005
SE	.0006	.0000	.0007
SSE	.0009	.0001	.0010
S	.0013	.0002	.0016
SSW	.0020	.0006	.0026
SW	.0041	.0009	.0050
WSW	.0026	.0008	.0035
W	.0020	.0006	.0026
WNW	.0019	.0006	.0024
NW	.0017	.0003	.0020
NNW	.0011	.0004	.0015
TOTAL	.0229	.0053	.0282

STABILITY CATEGORY B

DIRECTION (SECTOR)	WIND SPEED (M/SEC) 0-1.5	1.6-3.0	3.1-5.1	TOTAL
N	.0044	.0011	.0006	.0061
NNE	.0032	.0010	.0004	.0046
NE	.0053	.0005	.0001	.0059
ENE	.0025	.0003	.0001	.0030
E	.0026	.0002	.0001	.0029
ESE	.0013	.0002	.0000	.0015
SE	.0039	.0007	.0001	.0047
SSE	.0047	.0008	.0005	.0060
S	.0073	.0014	.0009	.0096
SSW	.0091	.0029	.0021	.0141
SW	.0105	.0037	.0030	.0173
WSW	.0053	.0026	.0020	.0099
W	.0046	.0017	.0012	.0074
WNW	.0056	.0022	.0013	.0091
NW	.0053	.0019	.0009	.0080
NNW	.0056	.0019	.0012	.0088
TOTAL	.0812	.0231	.0144	.1188

STABILITY CATEGORY C

DIRECTION (SECTOR)	WIND SPEED (M/SEC) 0-1.5	1.6-3.0	3.1-5.1	5.2-8.2	8.3-10.8	>10.8	TOTAL
N	.0020	.0017	.0025	.0001	.0001	.0000	.0064
NNE	.0012	.0013	.0017	.0001	.0000	.0000	.0042
NE	.0026	.0012	.0011	.0000	.0000	.0000	.0050
ENE	.0017	.0008	.0006	.0000	.0000	.0000	.0031
E	.0015	.0007	.0002	.0000	.0000	.0000	.0024
ESE	.0006	.0003	.0002	.0000	.0000	.0000	.0011
SE	.0018	.0008	.0009	.0001	.0000	.0000	.0036
SSE	.0020	.0016	.0022	.0001	.0000	.0000	.0059
S	.0034	.0025	.0049	.0004	.0003	.0001	.0116
SSW	.0029	.0035	.0090	.0010	.0010	.0010	.0184
SW	.0037	.0030	.0071	.0010	.0007	.0006	.0161
WSW	.0012	.0016	.0042	.0006	.0002	.0001	.0079
W	.0015	.0012	.0020	.0001	.0000	.0000	.0048
WNW	.0013	.0015	.0025	.0001	.0000	.0000	.0054
NW	.0015	.0015	.0029	.0001	.0000	.0000	.0059
NNW	.0018	.0018	.0048	.0003	.0002	.0001	.0089
TOTAL	.0307	.0249	.0467	.0040	.0026	.0019	.1107

STABILITY CATEGORY D

DIRECTION (SECTOR)	WIND SPEED (M/SEC) 0-1.5	1.6-3.0	3.1-5.1	5.2-8.2	8.3-10.8	>10.8	TOTAL
N	.0018	.0020	.0085	.0058	.0021	.0006	.0208
NNE	.0015	.0013	.0064	.0036	.0010	.0003	.0141
NE	.0025	.0020	.0058	.0022	.0004	.0001	.0130
ENE	.0012	.0016	.0027	.0008	.0002	.0000	.0065
E	0015	.0011	.0020	.0002	.0000	.0000	.0048
ESE	.0008	.0006	.0014	.0006	.0001	.0000	.0035
SE	.0019	0015	.0070	.0028	.0005	.0001	.0138
SSE	.0021	.0024	.0202	.0123	.0028	.0007	.0407
S	.0034	.0030	.0200	.0165	.0076	.0031	.0536
SSW	.0027	.0038	.0154	.0197	.0168	.0144	.0728
SW	.0026	.0025	.0057	.0078	.0050	.0045	.0281
WSW	.0014	.0014	.0025	.0025	.0016	.0005	.0098
W	.0015	.0010	.0013	.0007	.0002	.0000	.0047
WNW	0013	.0010	.0023	.0013	.0004	.0002	.0064
NW	.0023	0018	.0050	.0039	.0022	.0004	.0156
NNW	0020	.0024	.0113	.0105	.0049	.0021	.0332
TOTAL	.0304	0292	.1177	.0913	.0458	.0269	.3413

STABILITY CATEGORY E

DIRECTION (SECTOR)	WIND SPEED (M/SEC) 1.6-3.0	3.1-5.1	TOTAL
N	.0026	.0064	.0090
NNE	.0026	.0074	.0100
NE	.0048	.0117	.0166
ENE	.0035	.0048	.0083
E	.0028	.0018	.0046
ESE	.0014	.0017	.0032
SE	.0025	.0067	.0092
SSE	.0041	.0169	.0210
S	.0043	.0136	.0179
SSW	.0031	.0054	.0085
SW	.0022	.0020	.0042
WSW	.0008	.0004	.0012
W	.0004	.0004	.0008
WNW	.0007	.0005	.0012
NW	.0012	.0019	.0031
NNW	.0019	.0042	.0061
TOTAL	.0389	.0859	.1248

STABILITY CATEGORY F

DIRECTION (SECTOR)	WIND SPEED (M/SEC) 0-1.5	1.6-3.0	TOTAL	ANNUAL WIND DIRECTION DISTRIBUTION
N	.0122	.0057	.0179	.0617
NNE	.0127	.0072	.0199	.0541
NE	.0337	.0165	.0502	.0918
ENE	.0180	.0105	.0285	.0498
E	.0175	.0062	.0237	.0390
ESE	.0069	.0026	.0096	.0193
SE	.0135	.0052	.0187	.0507
SSE	.0156	.0074	.0230	.0975
S	.0160	.0075	.0235	.1178
SSW	.0112	.0052	.0164	.1327
SW	.0094	.0027	.0120	.0826
WSW	.0029	.0008	.0037	.0361
W	.0033	.0008	.0041	.0244
WNW	.0038	.0013	.0051	.0297
NW	.0062	.0021	.0082	.0429
NNW	.0074	.0043	.0117	.0701
TOTAL	.1903	.0860	.2763	

Table 2-12 lists, for the various combinations of wind-speed and stability categories, the wind-profile exponents used in the concentration calculations. These exponents, which are the default values for the SHORTZ/LONGZ models, are principally based on the results obtained by Cramer, et al. (1972) for Dugway Proving Ground, Utah. The wind-profile exponents in Table 2-12 are also consistent with the results obtained by De Marrais (1959) at Brookhaven National Laboratory and by Touma (1977) for various locations in the United States.

The equation for the standard deviation of the vertical concentration distribution σ_z in the SHORTZ and LONGZ models includes the effects of entrainment on initial plume growth and relates σ_z directly to the vertical turbulent intensity or standard deviation of the wind elevation angle σ'_E. Similarly, the equation for the standard deviation of the lateral concentration distribution σ_y in the SHORTZ model includes the effects of entrainment on initial plume growth and relates σ_y directly to the lateral turbulent intensity or standard deviation of the wind azimuth angle σ'_A. Table 2-13 lists the hourly vertical and lateral turbulent intensities used in the concentration calculations. The turbulent intensities in Table 2-13, which are the values suggested by Cramer, et al. (1975) for rural areas, are the default values used by the SHORTZ/LONGZ models in their rural modes. Because the Delta Airport wind directions were reported to the nearest 22.5-degree sector, an N-hour lateral turbulent intensity (obtained using the $t^{1/5}$ law of Osipov, 1972 and others) was assigned to each hour of an N-hour period with the same wind direction and stability in the SHORTZ model calculations. For example, if D stability and the same wind direction were reported for 3 consecutive hours, the 1-hour σ'_A value for D stability was multiplied by 1.25 ($3^{1/5}$) and assumed to apply during each hour of the 3-hour period. The purpose of this adjustment was to account in part for the effects of the actual variability of the wind direction within the 22.5-degree sector. The preprocessor program for EPA short-term dispersion models modifies the reported wind directions by means of a random number generator to account for these effects.

TABLE 2-12

WIND-PROFILE EXPONENTS USED IN THE CONCENTRATION CALCULATIONS

Pasquill Stability Category	Wind Speed (m/sec)					
	0.0-1.5	1.6-3.0	3.1-5.1	5.2-8.2	8.3-10.8	>10.8
A	0.10	0.10	--	--	--	--
B	0.10	0.10	0.10	--	--	--
C	0.20	0.15	0.10	0.10	0.10	0.10
D	0.25	0.20	0.15	0.10	0.10	0.10
E	--	0.25	0.20	--	--	--
F	0.40	0.30	--	--	--	--

TABLE 2-13

HOURLY VERTICAL (σ'_E) AND LATERAL (σ'_A) TURBULENT INTENSITIES USED IN THE CONCENTRATION CALCULATIONS

Pasquill Stability Category	σ'_E (rad)	σ'_A (rad)
A	0.1745	0.2495
B	0.1080	0.1544
C	0.0735	0.1051
D	0.0465	0.0665
E	0.0350	0.0501
F	0.0235	0.0336

The location nearest the Lynndyl site for which detailed mixing depth statistics are available is Salt Lake City, Utah (Environmental Data Service, 1968). Figures 3-28 through 3-31 in the report by Cramer, et al. (1972) show that the early morning mixing depths at Salt Lake City are in good agreement with the median nighttime mixing depths at Dugway Proving Ground, which is located 75 kilometers north of the Lynndyl site. Although afternoon mixing depth measurements at Dugway Proving Ground are only made in support of mission requirements, our experience in analyzing data collected during field experiments at Dugway Proving Ground indicates that there is a good correspondence between the daytime mixing depths at Salt Lake City and Dugway Proving Ground. Additionally, the isopleths of mean early morning and afternoon mixing depths given by Holzworth (1972) suggest that Salt Lake City mixing depths are likely to be representative of mixing depths at the Lynndyl site. We therefore used the Salt Lake City seasonal median mixing depths given in Table 2-14 in the SHORTZ model concentration calculations and the annual median mixing depths in the LONGZ model concentration calculations. The median afternoon mixing depths at Salt Lake City were assigned to the unstable A, B and C stability categories; the median early morning mixing depths were assigned to the stable E and F stability categories; and the median early morning and afternoon mixing depths were averaged and assigned to the neutral D stability category.

The Briggs (1969; 1971; 1972) plume rise equations used by the SHORTZ/LONGZ models require the vertical potential temperature gradient and ambient air temperature as inputs. The vertical potential temperature gradients and ambient air temperatures used in the LONGZ model annual concentration calculations are given in Table 2-15. The potential temperature gradients in Table 2-15, which were also used in the SHORTZ model calculations, are based on the measurements of Luna and Church (1972), the Pasquill (1961) and Turner (1964) definitions of the Pasquill stability categories and our previous experience. The ambient air temperatures in Table 2-15 are based on hourly temperature measurements made at the Delta Airport during the period 1949 through 1954. The annual average afternoon temperature was assigned to the unstable A, B and C stability categories; the

TABLE 2-14

SEASONAL MEDIAN MIXING DEPTHS IN METERS
BASED ON SALT LAKE CITY DATA

Pasquill Stability Category	Wind Speed (m/sec)					
	0.0-1.5	1.6-3.0	3.1-5.1	5.2-8.2	8.3-10.8	>10.8
(a) Winter						
A	400	550	--	--	--	--
B	400	550	800	--	--	--
C	400	550	800	1,000	1,000	1,000
D	265	340	460	675	675	840
E	--	125	125	--	--	--
F	125	125	--	--	--	--
(b) Spring						
A	2,000	2,250	--	--	--	--
B	2,000	2,250	2,500	--	--	--
C	2,000	2,250	2,500	2,500	2,500	2,500
D	1,060	1,190	1,310	1,350	1,425	1,950
E	--	125	125	--	--	--
F	125	125	--	--	--	--
(c) Summer						
A	2,500	2,900	--	--	--	--
B	2,500	2,900	3,500	--	--	--
C	2,500	2,900	3,500	3,700	4,000	4,000
D	1,310	1,510	1,810	1,950	2,250	2,400
E	--	125	125	--	--	--
F	125	125	--	--	--	--
(d) Fall						
A	800	1,250	--	--	--	--
B	800	1,250	1,600	--	--	--
C	800	1,250	1,600	2,000	2,250	2,500
D	460	690	860	1,125	1,275	1,625
E	--	125	125	--	--	--
F	125	125	--	--	--	--

TABLE 2-14 (Continued)

Pasquill Stability Category	Wind Speed (m/sec)					
	0.0-1.5	1.6-3.0	3.1-5.1	5.2-8.2	8.3-10.8	>10.8
(e) Annual						
A	550	1,200	--	--	--	--
B	550	1,200	2,300	--	--	--
C	550	1,200	2,300	2,800	2,800	2,800
D	340	660	1,210	1,460	1,460	1,460
E	--	125	125	--	--	--
F	125	125	--	--	--	--

TABLE 2-15

VERTICAL POTENTIAL TEMPERATURE GRADIENTS IN DEGREES KELVIN PER METER USED IN THE SHORTZ/LONGZ MODEL CALCULATIONS AND AMBIENT AIR TEMPERATURES IN DEGREES KELVIN USED IN THE LONGZ MODEL CALCULATIONS

Pasquill Stability Category	Potential Temperature Gradient (°K/m) for Wind Speed (m/sec) of:						Ambient Air Temperature (°K)
	0.0-1.5	1.6-3.0	3.1-5.1	5.2-8.2	8.3-10.8	10.8	
A	0.000	0.000	--	--	--	--	290
B	0.000	0.000	0.000	--	--	--	290
C	0.000	0.000	0.000	0.000	0.000	0.000	290
D	0.020	0.010	0.005	0.000	0.000	0.000	285
E	--	0.020	0.010	--	--	--	279
F	0.040	0.030	--	--	--	--	279

annual average nighttime temperature was assigned to the stable E and F stability categories; and the annual average temperature was assigned to the neutral D stability category. The afternoon and nighttime hours were defined as follows:

- Afternoon - Sunrise plus 5 hours to sunset minus 1 hour
- Night - Sunset plus 2 hours to sunrise plus 1 hour

It is the current policy of the UBAQ that calculated concentrations should be adjusted from ambient conditions to standard conditions (sea level pressure and a temperature of 298 degrees Kelvin) following the same procedures as used by the original version of the EPA Valley Model (Burt, 1977). The mean annual temperature at the Delta Airport is 285 degrees Kelvin and the mean annual pressure is approximately 850 millibars, leading to a correction factor of 1.14. All of the calculated concentrations in this report were converted to standard conditions by multiplying by 1.14. We point out that the same correction to standard conditions was applied in the dispersion model calculations described in our August 1978 and June 1981 reports.

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SECTION 3

CALCULATION PROCEDURES AND RESULTS

3.1 MAXIMUM GROUND-LEVEL CONCENTRATIONS

Annual Average Concentrations

We used the source inputs given in Section 2.1 and the meteorological inputs described in Section 2.2 with the LONGZ model to calculate annual average ground-level SO_2, NO_2 and particulate concentrations attributable to emissions from the IGS. The calculation grid for the stack emissions consisted of 441 receptors spaced at 1-kilometer intervals on a 20-kilometer by 20-kilometer grid approximately centered on the plant site. The elevations of these receptors were extracted from USGS topographic maps for use in the LONGZ model calculations. Because the maximum off-property ground-level concentrations of particulates from the low-level sources will occur at the property boundary, we also placed discrete receptors at 400-meter intervals around the property boundary and at 400-meter intervals 200 meters beyond the property boundary in order to ensure the detection of the maximum annual average particulate concentration attributable to emissions from the low-level sources and to provide a more detailed resolution of the particulate concentration field near the IGS property boundary. As discussed in Sections 1.4 and 2.1, the effects of gravitational settling and dry deposition were included in the LONGZ model particulate concentration calculations for emissions from the low-level sources at the IGS.

The calculated isopleths of annual average ground-level concentrations of SO_2, NO_2 and particulates attributable to emissions from the IGS are shown in Figures 3-1, 3-2 and 3-3, respectively. As shown by Figures 3-1 and 3-2, the maximum annual impact of the IGS stack emissions is calculated to occur about 7.1 kilometers north-northeast of the stack. On the other hand, Figure 3-3 shows that the maximum annual impact of the combined particulate emissions from the stack and the low-level sources is calculated

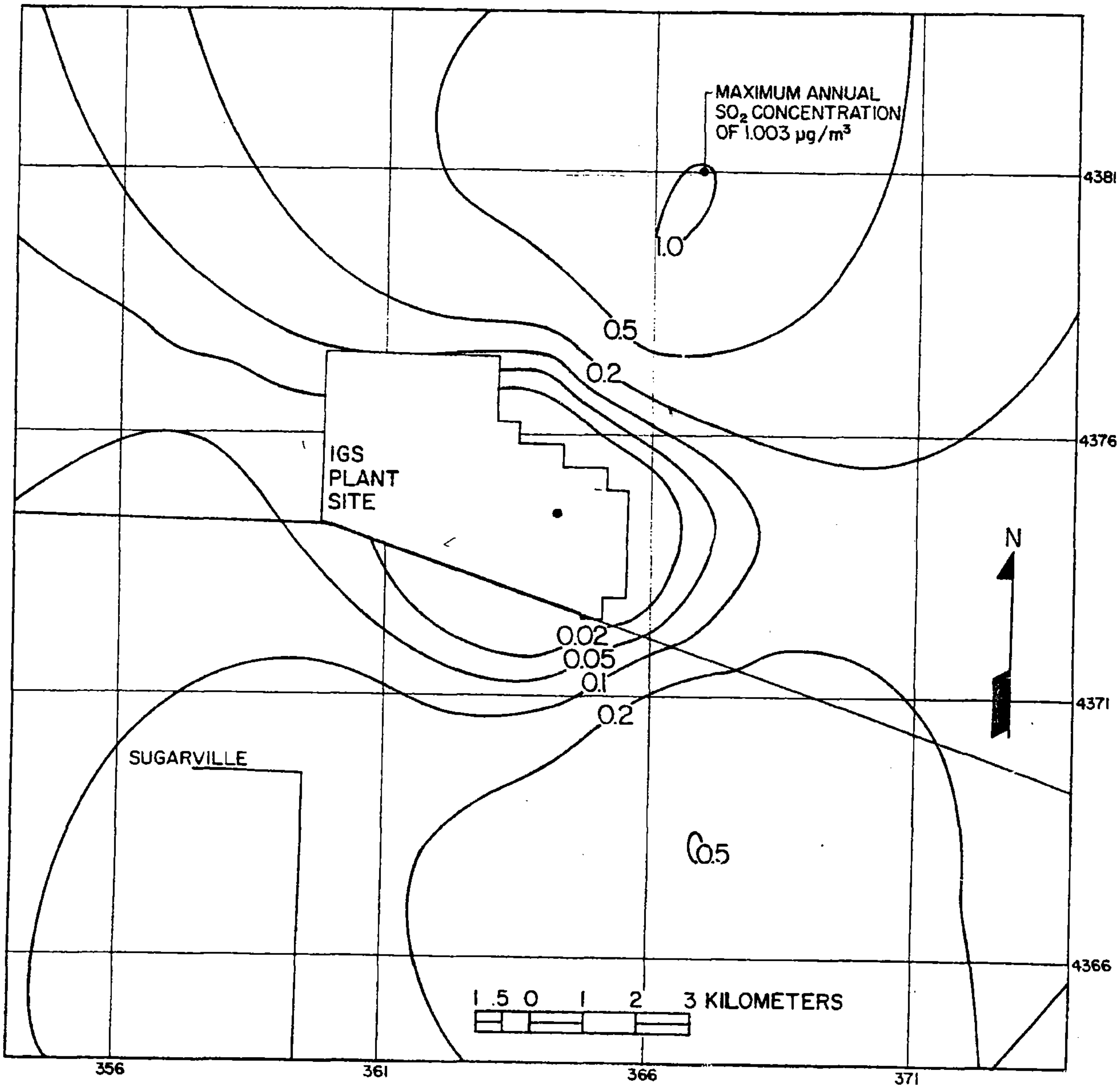

FIGURE 3-1. Calculated isopleths of annual average ground-level SO_2 concentration in micrograms per cubic meter attributable to emissions from the IGS.

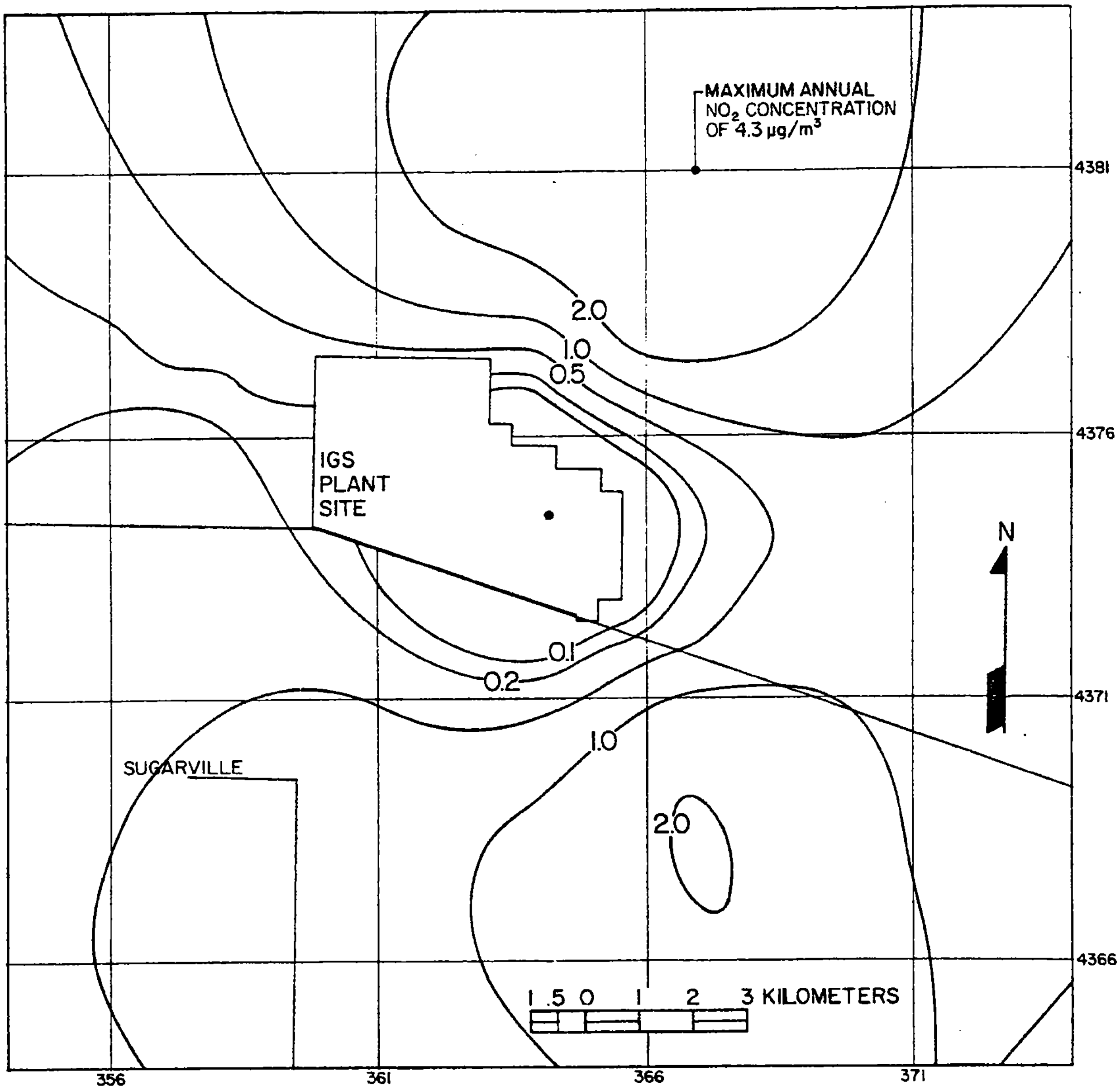

FIGURE 3-2. Calculated isopleths of annual average ground-level NO_2 concentration in micrograms per cubic meter attributable to emissions from the IGS.

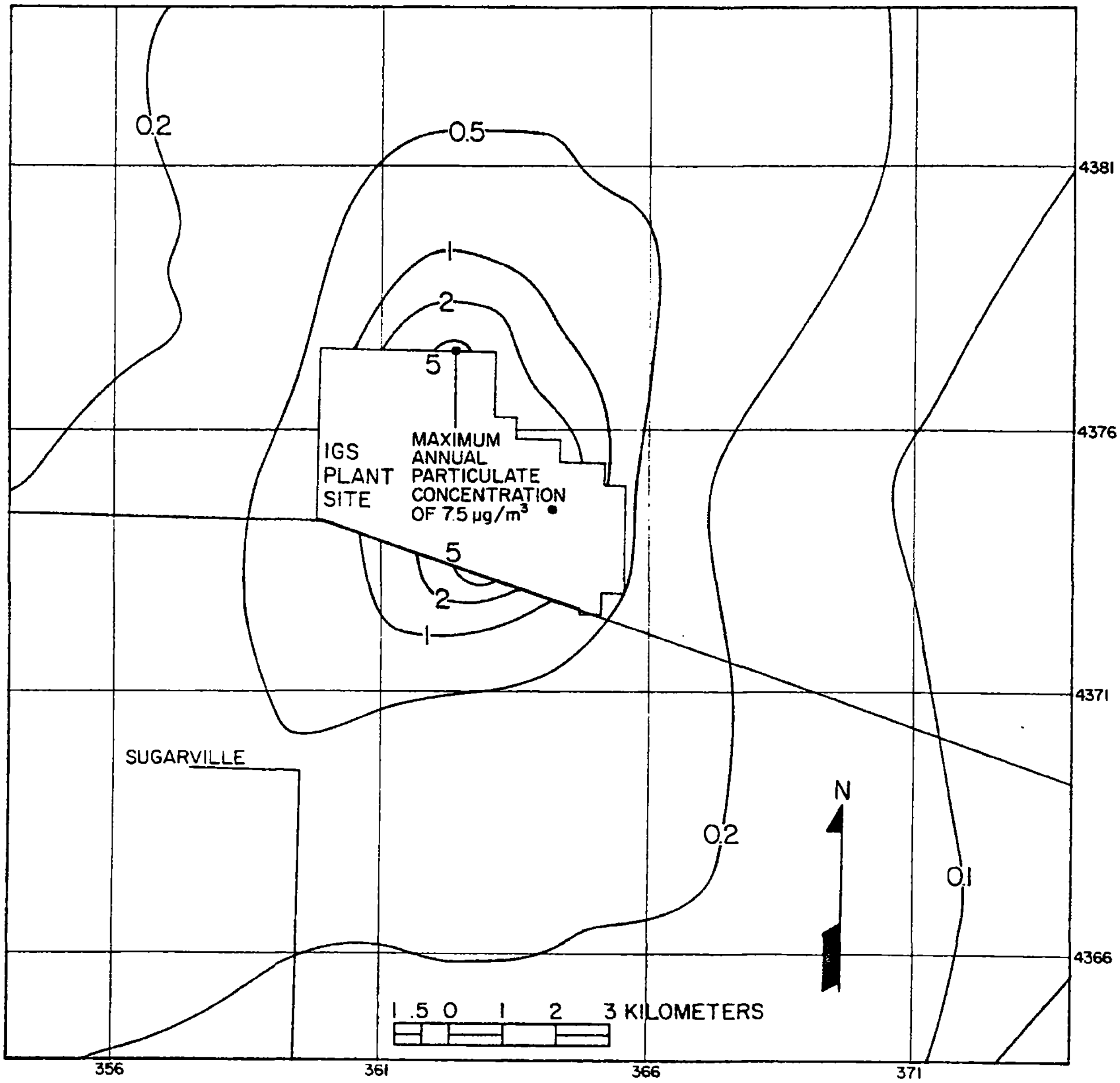

FIGURE 3-3. Calculated isopleths of annual average ground-level particulate concentration in micrograms per cubic meter attributable to emissions from the IGS.

to occur at the property boundary about 3.5 kilometers north-northwest of the stack. Table 3-1 gives the magnitudes and locations of the maximum annual average ground-level SO_2, NO_2 and particulate concentrations calculated for emissions from the IGS. The single stack is the only source of SO_2 and NO_2 emissions. The contributions of the various particulate sources to the maximum annual average particulate concentration calculated for the combined emissions from the IGS are listed in Table 3-2. As shown by Table 3-2, about 99.9 percent of this maximum concentration is determined by emissions from the low-level sources. Bowers, et al. (1979, p. 2-51) caution that the gravitational settling/dry deposition algorithms that we added to the SHORTZ/LONGZ models for use in the study described in this report (see Section 1.4) may violate mass continuity if applied in complex terrain. Because the maximum particulate concentration calculated for the combined emissions from the stack and the low-level sources occurs on flat terrain at the IGS property boundary, the accuracy of this calculated concentration is not affected by any failure to maintain mass continuity.

24-Hour Average Concentrations

The meteorological conditions that maximize the 24-hour average ground-level concentrations produced by buoyant stack emissions generally differ from the meteorological conditions that maximize the 24-hour average ground-level concentrations produced by nonbuoyant low-level emissions. For buoyant stack emissions in open terrain, both theory (Pasquill, 1974 and others) and air quality data (Gorr and Dunlap, 1977 and others) indicate that the highest 24-hour average concentrations occur during periods of persistent moderate-to-strong winds in combination with neutral stability. Additionally, following the terrain adjustment procedures used by the SHORTZ/LONGZ models, the highest 24-hour average concentrations calculated for buoyant stack emissions in complex terrain usually occur when persistent moderate-to-strong winds blow toward nearby elevated terrain. As part of the dispersion model analysis described in our August 1978 report, we determined that:

TABLE 3-1

MAGNITUDES AND LOCATIONS OF MAXIMUM ANNUAL AVERAGE GROUND-LEVEL SO_2, NO_2 AND PARTICULATE CONCENTRATIONS CALCULATED FOR EMISSIONS FROM THE IGS

Pollutant	Concentration ($\mu g/m^3$)	Location*	
		Distance (km)	Azimuth Bearing (deg)
SO_2	1.0	7.1	023
NO_2	4.3	7.1	023
Particulates	7.5	3.5	328

* Locations are with respect to the IGS stack.

TABLE 3-2

CONTRIBUTIONS OF THE INDIVIDUAL SOURCES TO THE MAXIMUM ANNUAL AVERAGE GROUND-LEVEL PARTICULATE CONCENTRATION CALCULATED FOR EMISSIONS FROM THE IGS

Source(s)	Concentration ($\mu g/m^3$)	Percentage of Total Concentration
Stack	0.01	0.1
Reserve Coal Storage	0.01	0.1
Active Coal Storage	0.02	0.3
Coal Handling	0.16	2.1
Limestone Handling	0.01	0.1
Limestone Storage	<0.01	<0.1
Flyash Handling	0.03	0.4
Solid Waste Hauling	6.32	84.2
Soil Stockpile	0.14	1.9
Waste Disposal Pile	0.29	3.9
Paved Haul Road	0.32	4.3
Unpaved Access Road	0.19	2.5
All Sources	7.51	100.0

- The wind directions during periods of persistent moderate-to-strong winds at the Delta Airport tend to be parallel to the axis of the valley

- Significant elevated terrain features are so far from the IGS plant site that the maximum 24-hour average concentrations calculated by the SHORTZ model for the stack emissions on elevated terrain are considerably less than the maximum 24-hour average concentrations calculated within about 4 kilometers of the plant site during periods of persistent moderate-to-strong winds

We therefore selected the three "worst-case" 24-hour periods of persistent moderate-to-strong winds from our August 1978 study for use in the 24-hour average concentration calculations for the IGS stack emissions. The hourly meteorological inputs for these periods are contained in Appendix B.

We used the stack source inputs given in Section 2.1 and the hourly meteorological inputs listed in Appendix B for the three "worst-case" 24-hour periods for the stack emissions with the SHORTZ model to calculate hourly and 24-hour average ground-level SO_2 concentrations. Concentrations were calculated for the regularly-spaced grid described above and for additional receptors placed at 500-meter intervals along the trajectories defined by the most frequent wind directions during the three "worst-case" 24-hour periods. For the 24-hour period with the highest calculated 24-hour average SO_2 concentration (the period 2200 MST on 22 June 1950 through 2100 MST on 23 June 1950), we repeated the SHORTZ model calculations with a 100-meter spacing of receptors in the vicinity of the calculated maximum concentration. The terrain elevations of all receptors were extracted from USGS topographic maps for use in the SHORTZ model calculations.

If nonbuoyant low-level emissions are independent of wind speed, the meteorological conditions associated with the maximum 24-hour average ground-level concentrations produced by these emissions are, in theory, stable to neutral conditions in combination with light-to-moderate winds that persist within a narrow sector for a number of hours. However, some of the low-level sources of particulate emissions at the IGS (the storage piles) are assumed to have no emissions to the atmosphere except when the mean wind speed is above about 5.4 meters per second (12 miles per hour). Additionally, because moderate-to-strong winds tend to be far more persistent within a narrow sector than light-to-moderate winds, the maximum 24-hour average concentration attributable to nonbuoyant low-level emissions at some geographic locations may be associated with periods of persistent moderate-to-strong winds rather than with periods of light-to-moderate winds. Moderate-to-strong winds also minimize the transport time of emissions to the property boundary and thus minimize the losses of particulates by gravitational settling and dry deposition within the property boundary. We therefore considered two sets of "worst-case" 24-hour periods for low-level particulate emissions from the IGS. The first set consisted of the three "worst-case" 24-hour periods of persistent moderate-to-strong winds discussed above that were used in the SHORTZ model calculations for the stack emissions. To assist in the selection of the second set of "worst-case" 24-hour periods, we used our persistence search (PRSIST) data analysis program to analyze the 1949 through 1954 Delta Airport hourly wind observations to identify all periods when winds below 8 meters per second persisted within any 22.5-degree sector for 12 or more hours. We then used the results of this PRSIST analysis to select the three 24-hour periods which satisfied the following criteria: (1) maximum number of hours of winds within the same 22.5-degree sector, (2) maximum number of hours of stable or neutral conditions, and (3) minimum average wind speed for the hours with winds within the most frequent 22.5-degree sector. The hourly meteorological inputs for these additional "worst-case" 24-hour periods are also contained in Appendix B.

We used the source inputs given in Section 2.1 for all particulate sources and the hourly meteorological inputs listed in Appendix B for the six "worst-case" 24-hour periods with the SHORTZ model to calculate hourly and 24-hour average ground-level particulate concentrations. Concentrations were calculated for the regularly-spaced grid described above and for discrete receptors placed at 200-meter intervals around the IGS property boundary and at 200-meter intervals 200 meters beyond the property boundary. The effects of gravitational settling and dry deposition were included in the SHORTZ model calculations for emissions from the low-level sources at the IGS. The "worst-case" 24-hour period for the combined particulate emissions, 1900 MST on 29 July 1952 through 1800 MST on 30 July 1952, was a period of persistent light-to-moderate winds.

The calculated isopleths of "worst-case" 24-hour average ground-level concentrations of SO_2 and particulates attributable to emissions from the IGS are shown in Figures 3-4 and 3-5, respectively. As shown by Figure 3-4, the maximum 24-hour impact of the SO_2 emissions from the stack is calculated to occur about 4.0 kilometers north-northeast of the stack. On the other hand, Figure 3-5 shows that the maximum 24-hour impact of the combined particulate emissions from the stack and the low-level sources is calculated to occur at the IGS property boundary about 3.4 kilometers north-northwest of the stack. Table 3-3 gives the magnitudes and locations of the maximum 24-hour average SO_2 particulate concentrations calculated for emissions from the IGS. Table 3-4 lists the contributions of the individual sources to the maximum 24-hour average particulate concentration calculated for the combined emissions. As is the case with the maximum annual average particulate concentration calculated for the combined emissions, about 99.9 percent of the calculated maximum 24-hour average concentration is determined by emissions from the low-level sources.

3-Hour Concentrations

High 3-hour average concentrations attributable to buoyant stack emissions can occur during periods of persistent moderate-to-strong winds, periods of transition from a stable thermal stratification to an unstable stratification or vice versa, and periods with limited mixing. We define limited mixing as a period of light-to-moderate winds in combination with unstable to slightly stable conditions with the IGS plume contained within a relatively shallow mixing layer. (This definition of limited mixing differs from the TVA definition (Carpenter, et al., 1971) which is restricted

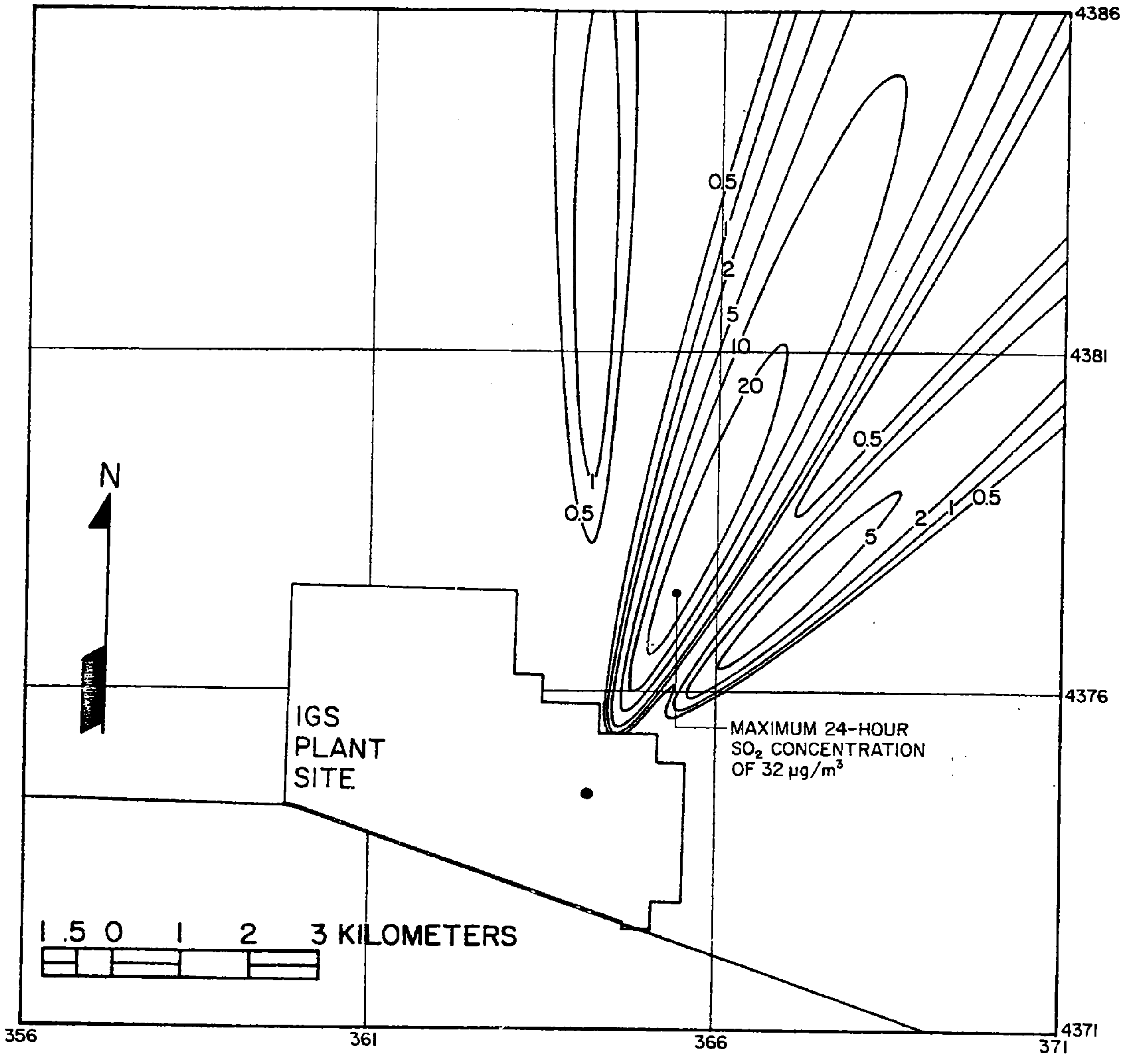

FIGURE 3-4. Calculated isopleths of 24-hour average ground-level SO_2 concentration in micrograms per cubic meter attributable to emissions from the IGS during the "worst-case" 24-hour period (2200 MST on 22 June 1950 through 2100 MST on 23 June 1950).

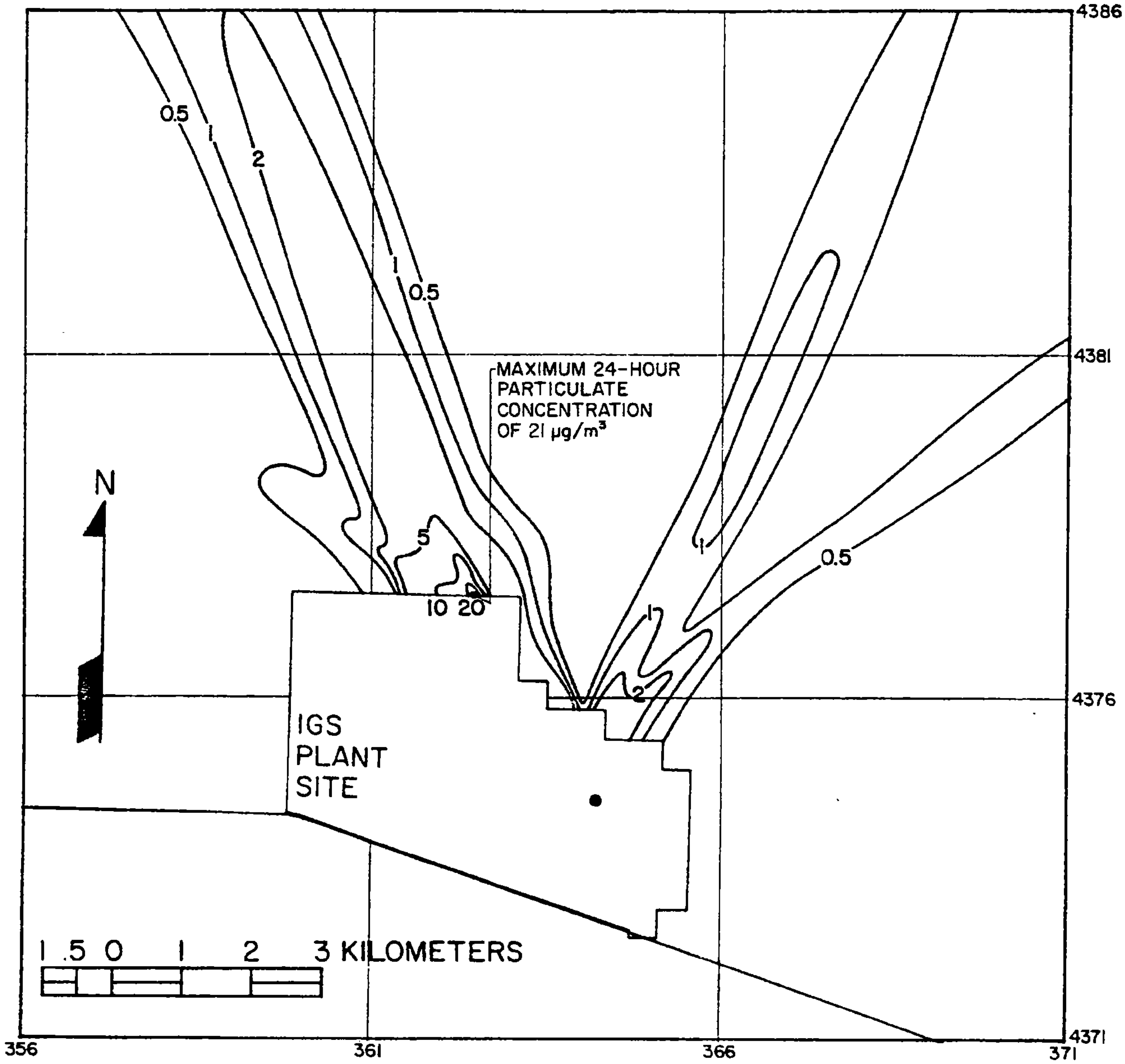

FIGURE 3-5. Calculated isopleths of 24-hour average ground-level particulate concentration in micrograms per cubic meter attributable to emissions from the IGS during the "worst-case" 24-hour period (1900 MST on 29 July 1952 through 1800 MST on 30 July 1952).

TABLE 3-3

MAGNITUDES AND LOCATIONS OF MAXIMUM 24-HOUR AVERAGE GROUND-LEVEL SO_2 AND PARTICULATE CONCENTRATIONS CALCULATED FOR EMISSIONS FROM THE IGS

Pollutant	Concentration ($\mu g/m^3$)	Location*	
		Distance (km)	Azimuth Bearing (deg)
SO_2	32	4.0	023
Particulates	21	3.4	331

* Locations are with respect to the IGS stack.

TABLE 3-4

CONTRIBUTIONS OF THE INDIVIDUAL SOURCES TO THE MAXIMUM 24-HOUR AVERAGE GROUND-LEVEL PARTICULATE CONCENTRATION CALCULATED FOR EMISSIONS FROM THE IGS

Source(s)	Concentration ($\mu g/m^3$)	Percentage of Total Concentration
Stack	<0.1	<0.5
Reserve Coal Storage	<0.1	<0.5
Active Coal Storage	<0.1	<0.5
Coal Handling	0.6	2.8
Limestone Handling	<0.1	<0.5
Limestone Storage	<0.1	<0.5
Flyash Handling	0.6	2.8
Solid Waste Handling	17.2	80.4
Soil Stockpile	0.2	0.9
Waste Disposal Pile	2.0	9.3
Paved Haul Road	0.5	2.3
Unpaved Access Road	0.2	0.9
All Sources	21.4	100.0

to daytime hours during periods of fair weather with light-to-moderate winds below an elevated subsidence inversion.) All three meteorological regimes were considered in the study described in our August 1978 report. From the "worst-case" 3-hour periods considered in our 1978 dispersion model calculations, we selected three 3-hour periods of persistent strong winds, two 3-hour transition periods and three 3-hour limited mixing periods for use in the 3-hour average concentration calculations described in this report. The hourly meteorological inputs for these periods are listed in Appendix B. The 3-hour concentration calculations were performed following modeling techniques identical to those described above in the discussion of the 24-hour average SO_2 concentration calculations for the IGS stack emissions.

Figure 3-6 shows the calculated isopleths of 3-hour average ground-level SO_2 concentrations attributable to emissions from the IGS during the "worst-case" 3-hour period, which is 2200 through 2400 MST on 1 December 1951. Following our definition of limited mixing, this 3-hour period was a period of limited mixing in combination with winds from the south-southwest. The calculated maximum 3-hour average ground-level SO_2 concentration of 80 micrograms per cubic meter is located 6.7 kilometers north-northeast of the stack.

3.2 COMPARISON OF CALCULATED MAXIMUM CONCENTRATIONS WITH PSD INCREMENTS AND NAAQS

PSD Increments

The area surrounding the IGS plant site (see Figure 1-1) is a Class II (moderate growth) Prevention of Significant Deterioration (PSD) area. Table 3-5 lists the SO_2 and particulate PSD Increments for Class II areas. (No PSD Increments exist for pollutants other than SO_2 and particulates.) The calculated maximum ground-level SO_2 and particulate concentrations given in Section 3.1 are expressed as percentages of the

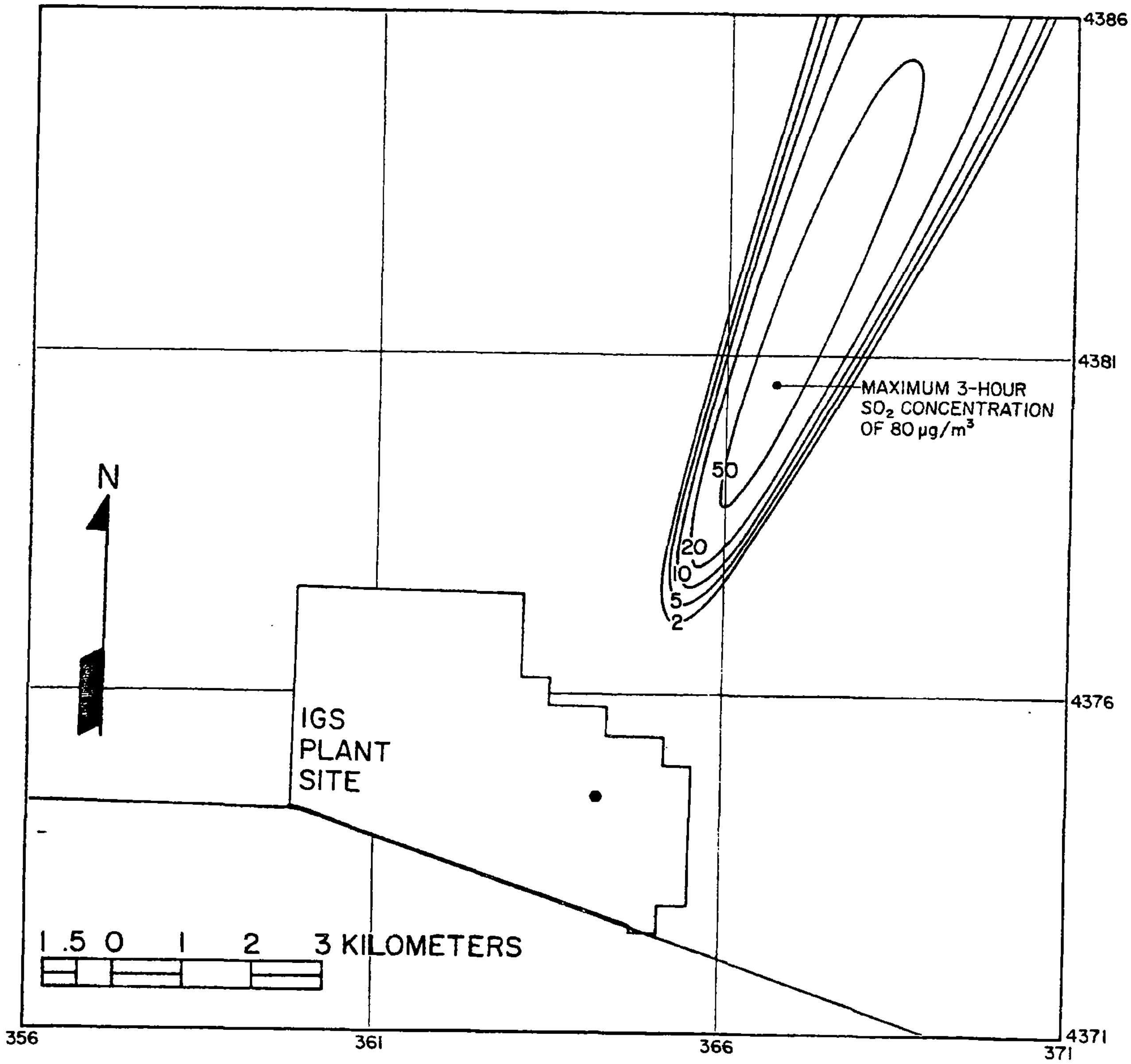

FIGURE 3-6. Calculated isopleths of 3-hour average ground-level SO_2 concentration in micrograms per cubic meter attributable to emissions from the IGS during the "worst-case" 3-hour period (2200 through 2400 MST on 1 December 1951).

TABLE 3-5

PREVENTION OF SIGNIFICANT DETERIORATION (PSD) INCREMENTS
FOR CLASS II AREAS

Pollutant	Averaging Time	PSD Increment ($\mu g/m^3$)
SO_2	3 Hours	512
	24 Hours	91
	Annual	20
Particulates	24 Hours	37
	Annual*	19

* Annual geometric mean.

TABLE 3-6

CALCULATED MAXIMUM SHORT-TERM AND ANNUAL AVERAGE GROUND-LEVEL SO_2 AND PARTICULATE CONCENTRATIONS EXPRESSED AS PERCENTAGES OF THE CORRESPONDING CLASS II PSD INCREMENTS

Pollutant	Averaging Time	Maximum Concentration (% of Class II PSD Increment)
SO_2	3 Hours	15.6
	24 Hours	35.2
	Annual	5.0
Particulates	24 Hours	56.8
	Annual	39.5

corresponding Class II PSD Increments for SO_2 and particulates in Table 3-6. Inspection of Table 3-6 shows that:

- The calculated maximum 3-hour average SO_2 concentration of 80 micrograms per cubic meter is about 16 percent of the 3-hour Class II PSD Increment for SO_2 of 512 micrograms per cubic meter

- The calculated maximum 24-hour average SO_2 concentration of 32 micrograms per cubic meter is about 35 percent of the 24-hour Class II PSD Increment for SO_2 of 91 micrograms per cubic meter

- The calculated maximum 24-hour average particulate concentration of 21 micrograms per cubic meter is about 57 percent of the 24-hour Class II PSD Increment for particulates of 37 micrograms per cubic meter

- The calculated maximum annual average SO_2 concentration of 1.0 microgram per cubic meter is about 5 percent of the annual Class II PSD Increment for SO_2 of 20 micrograms per cubic meter

- The calculated maximum annual average particulate concentration of 7.5 micrograms per cubic meter is about 39 percent of the annual Class II PSD Increment for particulates of 19 micrograms per cubic meter

Thus, the results of the dispersion model calculations indicate that no Class II PSD Increment will be exceeded as a result of emissions from the IGS.

The short-term PSD Increments may be exceeded at any given point once per year. That is, a short-term PSD Increment is violated on the second occasion during a year when a short-term concentration above the PSD Increment occurs at the same point. Additionally, short-term concentrations for standard clock hours and calendar days ("block averages") are normally used to assess compliance with the short-term PSD Increments. Because Table 3-6 gives the maximum (rather than highest of the second-highest) running-mean (rather than block-average) short-term concentrations calculated during a 6-year period as percentages of the corresponding Class II PSD Increments, Table 3-6 provides very safe-sided estimates of the percentages of the Class II PSD Increments accounted for by emissions from the IGS.

In addition to an assessment of the compliance of the IGS with the Class II PSD Increments, our August 1978 report also considered compliance with the Class I (pristine air quality) PSD Increments at the nearest existing and potential Class I areas, all of which are more than 100 kilometers from the IGS plant site. The results of the calculations described in our August 1978 report indicated that the Class I Increments would not be exceeded at any existing or potential Class I area. For the same total emissions, the differences between the plant configurations assumed in this report and in the August 1978 report are too small to affect the conclusions contained in the August 1978 report about the impact of emissions from the IGS at the long downwind distances of the existing and potential Class I areas. Because the total pollutant emissions from the IGS have been reduced by about a factor of 2, the negligible air quality impacts at the existing and potential Class I areas of emissions from the IGS that were estimated in the August 1978 report should be reduced by about a factor of 2.

The study described in this report includes the first dispersion model calculations by the H. E. Cramer Company of the air quality impact of particulate emissions from the low-level sources at the IGS, including emissions from fugitive sources such as haul road traffic. We did not include emissions from the low-level particulate sources in our previous dispersion model analyses for the IGS because the detailed design and engineering data required to assess the potential air quality impact of these emissions were not available. The calculated maximum 24-hour and annual average particulate concentrations presented in this report are higher than the corresponding concentrations given in our previous reports because the calculated maximum particulate concentrations in this report are for the combined emissions from the stack and low-level sources rather than for the emissions from the stack only.

NAAQS

Table 3-7 lists the National Ambient Air Quality Standards (NAAQS) for SO_2, particulates and NO_2. As is the case with the short-term PSD Increments, the short-term NAAQS may be exceeded at any given point once per year. In assessing the compliance of the IGS with the NAAQS, it is necessary to consider the combined effects of emissions from the IGS, emissions from other major pollutant sources and background pollutant concentrations. As discussed in Sections 1.3 and 2.1, there are no major SO_2, particulate or NO_2 sources in the vicinity of the IGS plant site. In the absence of onsite air quality data, we used the 1982 air quality data from the Utah Division of Health's air quality monitoring network to estimate the existing air quality in the vicinity of the IGS plant site (see Section 1.3). The annual average and maximum short-term pollutant concentrations given in Table 1-2 in Section 1.3 are assumed to represent the background concentrations in the vicinity of the IGS. Table 3-8 shows the calculated maximum ground-level SO_2, particulate and NO_2 concentrations with the effects of background included. Comparison of Tables 3-7 and 3-8 shows that no NAAQS is predicted to be exceeded as a result of emissions from the IGS.

Our August 1978 report also considered possible interactions of emissions from the IGS with emissions from the stationary pollutant sources located along the industrialized Wasatch Front. We concluded that significant interactions are unlikely because the IGS plant site and the Wasatch Front area are contained in different functional air basins. Following the EPA definition of a "significant" air quality impact, the results of the

TABLE 3-7

NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS) FOR SO_2, PARTICULATES AND NO_2

Pollutant	Averaging Time	NAAQS ($\mu g/m^3$)	
		Primary	Secondary
SO_2	3 Hours	-	1,300
	24 Hours	365	-
	Annual	80	-
Particulates	24 Hours	260	150
	Annual*	75	60
NO_2	Annual	100	-

* Annual geometric mean.

TABLE 3-8

CALCULATED MAXIMUM GROUND-LEVEL SO_2, PARTICULATE AND NO_2 CONCENTRATIONS WITH THE EFFECTS OF BACKGROUND INCLUDED

Pollutant	Averaging Time	Concentration ($\mu g/m^3$)		
		IGS	Background	Total
SO_2	3 Hours	80	26	106
	24 Hours	32	0	32
	Annual	1.0	0	1.0
Particulates	24 Hours	21	103	124
	Annual	7.5	39	46.5
NO_2	Annual	4.3	38	42.3

dispersion model calculations described in the August 1978 report indicated that emissions from the IGS will not have a significant impact at the nearest monitoring sites where violations of the NAAQS have been measured. Also, an extrapolation of the maximum observed SO_2 concentrations for the nearest monitoring site at which violations of the NAAQS for SO_2 have been measured to the area of maximum impact for emissions from the IGS indicated that emissions from the plant will not endanger the NAAQS for SO_2. For the same emissions, the differences between the plant configuration assumed in this report and in the August 1978 report are too small to affect the conclusions given in our August 1978 report about interactions of emissions from the IGS and the major sources along the Wasatch Front. As noted above, the total emissions from the plant configuration considered in this report are only about half of the total emissions considered in the August 1978 report.

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SECTION 4

IDENTIFICATION OF THE MAJOR AREAS OF UNCERTAINTY IN THE MODEL CALCULATIONS

The principal areas of uncertainty affecting the accuracy of the results of the dispersion model calculations described in this report are:

- The representativeness of the stack and emissions parameters given in Section 2.1 for the IGS
- The representativeness of the meteorological inputs used in the model calculations and discussed in Section 2.2
- The accuracy of the SHORTZ/LONGZ complex terrain dispersion models

The stack and emissions parameters for the IGS were provided to the H. E. Cramer Company by IPP and its consultant, Engineering-Science, Inc. For the purpose of this report, we assume that the stack and emissions parameters used in the model calculations are representative. However, we point out that the assumption implicit in the model calculations that "worst-case" short-term emissions coincide in time with "worst-case" short-term meteorological conditions is improbable and tends to bias the calculated maximum short-term concentrations toward overestimation.

We selected what we consider to be the best available data to develop the meteorological inputs used in our dispersion model calculations for the IGS. Because of the close proximity of the IGS plant site to the Delta, Utah Airport, we believe that the Delta Airport surface weather observations are representative of conditions at the site. On the basis of our experience at Dugway Proving Ground and the isopleths of mean mixing depths given by Holzworth (1972), we also believe that the Salt Lake City mixing depths used in the calculations are representative of the IGS plant site. The procedures that we used to assign turbulent intensities (i.e., dispersion coefficients) are the same as the procedures that we have used in many of our model evaluation studies. As indicated below, these procedures have resulted in good agreement between calculated and measured air quality for SO_2 sources located in complex terrain. The other meteorological inputs (wind-profile exponents and vertical potential temperature gradients) were based on measurements at similar locations and are believed to be representative of conditions in the vicinity of the IGS plant site.

It is not possible to demonstrate the accuracy of our dispersion model calculations for the IGS by means of direct comparison of concurrent calculated and observed concentrations. However, on the basis of previous studies for EPA of SO_2 sources located in complex terrain, we can specify approximate confidence intervals for our model calculations for the IGS stack emissions. Confidence intervals, in contrast to confidence limits which must satisfy strict statistical criteria, simply reflect the results of direct comparisons of model predictions with air quality observations without attempting to account for the effects of sample size and other limitations as must be done in the case of estimating confidence limits. In the cases where the plume from an isolated source was simultaneously detected by two or more SO_2 monitors (which allowed us to specify the wind direction at the plume height to within 1 or 2 degrees), the SHORTZ model yielded calculated hourly SO_2 concentrations that were, on the average, equal to the observed concentrations (see Cramer, et al., 1976). Individual calculated and observed hourly SO_2 concentrations differed by as much as a factor of two. To a large extent, we believe that the discrepancies between the individual calculated and observed hourly concentrations were caused by errors in the source and meteorological inputs and possibly in the air quality measurements. When unadjusted surface wind directions were used in the SHORTZ model calculations, the calculated maximum 3-hour and 24-hour average SO_2 concentrations were, on the average, within 20 percent of the observed values (see Section 8 of Cramer, et al., 1975). Finkelstein (1976) also compared the results of the short-term model calculations in the Cramer, et al. (1975) study with the results of wind-tunnel simulations of various sources in the Clairton area of Allegheny County and concluded that, "...the agreement between the two studies is surprisingly and reassuringly close." The LONGZ model has yielded calculated annual average SO_2 concentrations within 20 percent of the observed values at all monitors where the annual average SO_2 concentrations were above the accuracy and threshold of the SO_2 monitors (Cramer, et al., 1975). In cases where the annual average concentrations were below the threshold of the SO_2 monitors, the LONGZ model has yielded calculated annual average SO_2 concentrations that were within plus or minus one-half the accuracy and threshold of the SO_2 instrument (Cramer, et al., 1976 and Wilson, et al., 1977).

The most rigorous test of the SHORTZ model to date was the recent application of the model to the Westvaco data set (Bowers, et al., 1983). The 190-meter Westvaco Main Stack is located in a deep river valley with terrain elevations as much as 200 meters above the stack-top elevation within a 1.5 kilometers of the stack. Data from nine SO_2 air quality monitors with elevations ranging from 26 to 195 meters above the stack top were used to evaluate the performance of the SHORTZ model and four other complex terrain dispersion models. The detailed onsite meteorological measurements enabled the direct development of all SHORTZ hourly meteorological inputs without recourse to the use of discrete stability categories to assign default values of model input parameters. Because of the extremely large and unique vertical wind-direction shears found at times in the onsite wind measurements, the Cramer, et al. (1972) wind shear term was added to the SHORTZ model's lateral dispersion coefficient equation for use in the model performance evaluation. At the three monitoring sites on elevated terrain at and beyond the distance to plume stabilization, the SHORTZ model was the only one of the five models evaluated that yielded unbiased predictions of the 25 highest 1-hour, 3-hour and 24-hour average SO_2 concentrations. For example, Figure 4-1 compares the cumulative frequency distributions of the 25 highest calculated and observed 24-hour average concentrations at Monitor 9, the monitor with the highest elevation above the stack top. On the other hand, the SHORTZ model showed a consistent bias toward overestimation at the six monitoring sites on elevated terrain within the distance to plume stabilization. This bias is illustrated by Figure 4-2, which compares the cumulative frequency distributions of the 25 highest calculated and

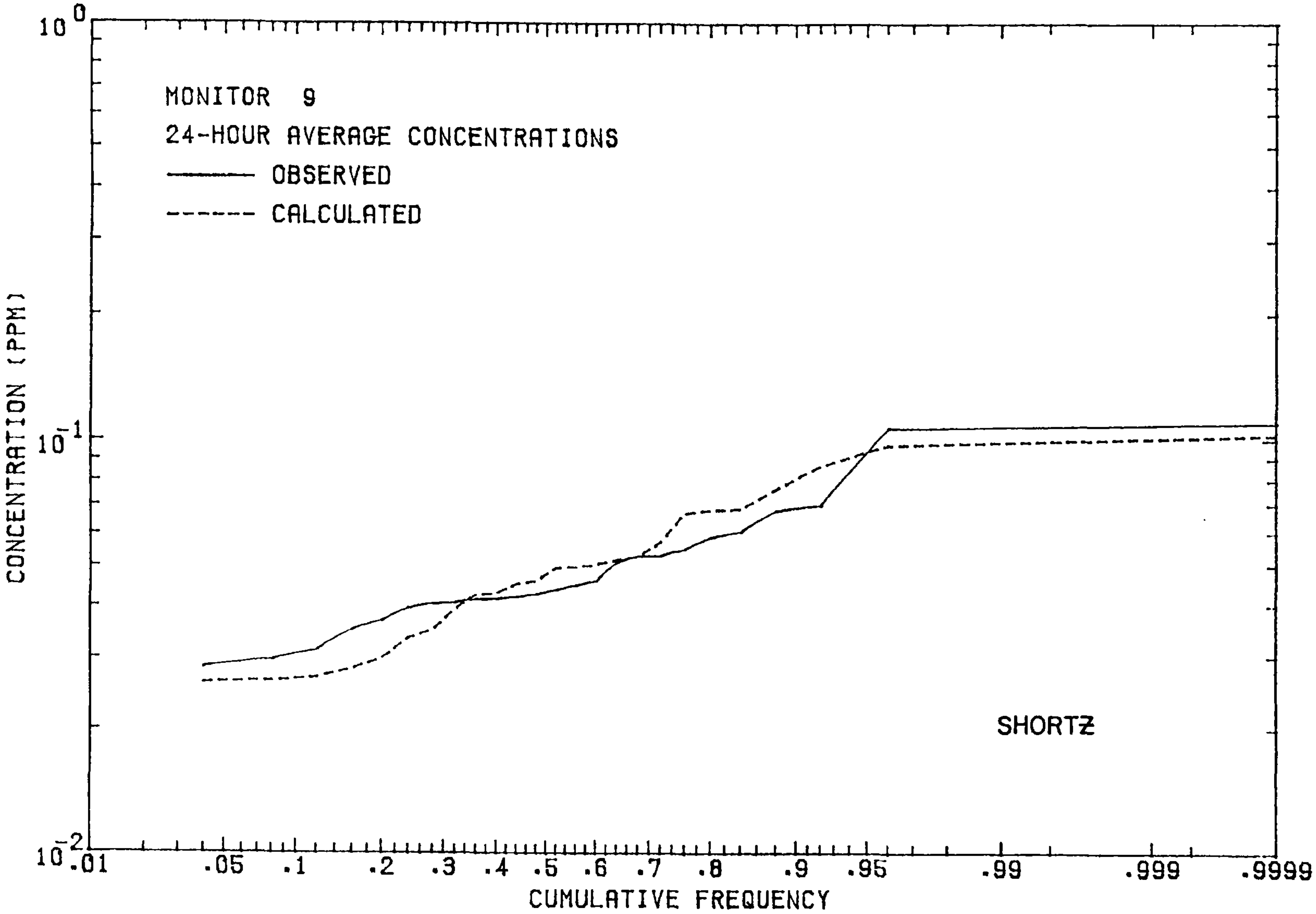

Figure 4-1. Comparison of the cumulative frequency distribution of the 25 highest observed (minus background) 24-hour average SO_2 concentrations at Monitor 9 during the second year of the Westvaco monitoring program with the cumulative frequency distribution of the 25 highest 24-hour average concentrations calculated by SHORTZ (from Bowers, et al., 1983).

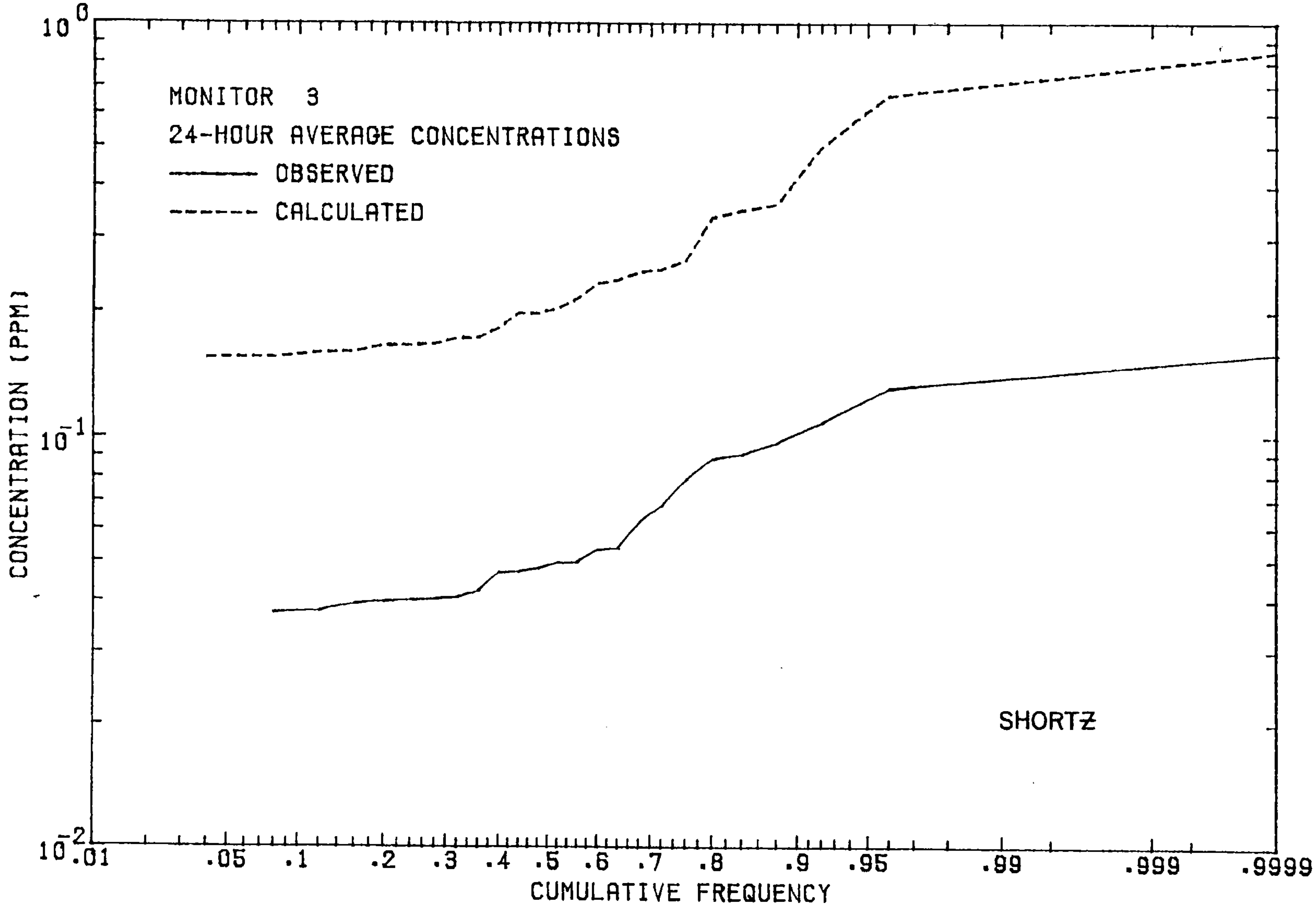

Figure 4-2. Comparison of the cumulative frequency distribution of the 25 highest observed (minus background) 24-hour average SO_2 concentrations at Monitor 3 during the second year of the Westvaco monitoring program with the cumulative frequency distribution of the 25 highest 24-hour average concentrations calculated by SHORTZ (from Bowers, et al., 1983).

observed 24-hour average concentrations at Monitor 3, the monitor nearest to the stack. Because no terrain features as high as the 216-meter IGS stack are located within the approximate 2-kilometer distance to plume stabilization, the results of the Westvaco model evaluation study indicate that the predictions of the SHORTZ model for the IGS stack emissions should be unbiased.

The accuracy of the particulate concentrations calculated by the SHORTZ/LONGZ models for emissions from the low-level sources at the IGS is more difficult to assess than the accuracy of the concentrations calculated for the stack emissions because this study is the first use in the SHORTZ/LONGZ models of the complete gravitational settling/dry deposition algorithms from the corresponding computer codes (ISCST/ISCLT) of the Industrial Source Complex (ISC) Dispersion Model (Bowers, et al., 1979). The performance of the ISC Model for low-level particulate emissions was evaluated by Bowers, et al. (1982) using emissions, meteorological and air quality data from the Armco Middletown, Ohio Steel Mill. When calculated and observed 24-hour and seasonal average particulate concentrations paired in space and time were compared, ISCST overpredicted the observed 24-hour average particulate concentrations by an average of 12 micrograms per cubic meter and ISCLT overpredicted the observed seasonal average particulate concentrations by an average of 4 micrograms per cubic meter. These biases toward overestimation were within 20 percent of the average observed concentrations. Assuming the accuracy of the SHORTZ/LONGZ models with the ISC Model's gravitational settling/dry deposition algorithms to be approximately the same as obtained in the Armco study, the 24-hour and annual average particulate concentrations calculated for emissions from the low-level sources at the IGS should, on the average, be accurate to within about 20 percent. If there is a bias in the results of the particulate concentration calculations, it is probably a bias toward overestimation.

In summary, we believe that the results of the concentration calculations presented in this report provide a realistic assessment of the potential air quality impact of emissions from the IGS. The hourly surface weather observations from the nearby Delta, Utah Airport for the 6-year period 1949 through 1954 form a data base that is unusually comprehensive for a remote location. The other meteorological inputs used in the model calculations are based on measurements at similar locations and are believed to be representative of conditions at the IGS plant site. Also, the SHORTZ/LONGS models have yielded a close correspondence between calculated and observed concentrations (at distances up to 30 kilometers from the source) for SO_2 sources located in terrain of greater complexity than the terrain within a 30-kilometer radius of the IGS plant site, and a performance evaluation of modeling techniques comparable to the techniques applied to the particulate emissions from the low-level sources at the IGS suggests that the concentrations calculated for these sources are probably accurate to within about 20 percent. If there is a bias in the particulate concentrations calculated for emissions from the low-level sources, it is likely to be a bias toward overestimation.

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APPENDIX A

DETERMINATION OF MAXIMUM COMBINED PARTICULATE EMISSIONS FROM THE SOLID WASTE SOIL STOCKPILE AND THE SOLID WASTE BURIAL PILE

As discussed in Section 2.1, the maximum combined particulate emissions from the solid waste soil stockpile and the solid waste burial pile at the IGS will occur sometime within the first 2.5 years of operation. Following the first 2.5 years of operation, emissions from the solid waste burial pile will remain approximately constant and there will be no soil stockpile. Because the two sources are adjacent, the maximum air quality impact of the combined emissions from the two sources has the potential to occur when the combined emissions from the two sources are at a maximum. In the dispersion model calculations described in this report, we arbitrarily assumed that the maximum combined emissions from the two sources will coincide in time with "worst-case" meteorological conditions. The following paragraphs discuss how we determined the maximum combined emissions from the two sources.

The particulate emission rate at time t for either the solid waste soil stockpile or the solid waste burial pile can be expressed as

$$Q\{t\} = E_f A\{t\}(1-E_c\{t\}) \qquad \text{(A-1)}$$

where

E_f = the uncontrolled emission factor

$A\{t\}$ = the area of the pile at time t

$E_c\{t\}$ = the emissions control efficiency at time t

The uncontrolled emission factor for the soil stockpile E_{fs} in pounds per acre per day is assumed to be (Engineering-Science, Inc., 1983)

$$E_{fs} = 0.48f \tag{A-2}$$

where f is the percent frequency of occurrence of wind speeds above 5.4 meters per second (12 miles per hour). The area of the soil stockpile is assumed to decrease linearly from 2.6 acres at the start of operation to zero acres after 2.5 years of operation (Engineering-Science, Inc., 1983), resulting in a soil stockpile area A_s at time t of

$$A_s\{t\} = 2.6(1 - \frac{t}{2.5}) \tag{A-3}$$

It follows from Equations (A-1) through (A-3) and a constant control efficiency E_c of 0.5 (50 percent) that the soil stockpile emission rate Q_s at time t is

$$Q_s\{t\} = 0.624f(1 - \frac{t}{2.5}) \tag{A-4}$$

Engineering-Science, Inc. (1983) gives the uncontrolled emission factor for the solid waste burial pile E_{fb} as a constant 2.08 pounds per acre per day. Assuming that the area of the burial pile linearly increases from zero at the start of operation of the IGS to 20.7 acres after 2.5 years of operation, the area of the burial pile A_b at time t is given by

$$A_b\{t\} = 8.28t \tag{A-5}$$

Similarly, if the areal average emission control efficiency is assumed to increase linearly from 0.50 to 0.75 (50 to 75 percent) over the first 2.5 years, the burial pile control efficiency E_{cb} at time t is

$$E_{cb}\{t\} = 0.5 + 0.1t \tag{A-6}$$

Combination of Equations (A-1), (A-5) and (A-6) and the uncontrolled emission factor of 2.08 gives the burial pile emission rate Q_b at time t as

$$Q_b\{t\} = 8.61t - 1.72t^2 \tag{A-7}$$

The total emission rate for the combined emissions from the soil stockpile and the solid waste burial pile is obtained by the summation of Equations (A-4) and (A-7), which yields

$$Q_T\{t\} = 0.624f + t(8.61 - 0.25f) - 1.72t^2 \tag{A-8}$$

Equation (A-8) is maximized with respect to time as follows:

$$\frac{\partial Q_T\{t\}}{\partial t} = (8.61 - 0.25f) - 3.44t = 0 \tag{A-9}$$

$$t_{max} = \frac{(8.61 - 0.25f)}{3.44} \tag{A-10}$$

The annual frequency of occurrence f of wind speeds above 5.4 meters per second at the Delta, Utah Airport is 17.2 percent. If this frequency is entered in Equation (A-10), the maximum combined emissions from the soil stockpile and the solid waste burial pile occur 1.25 years after the start of operation of the IGS.

We used Equations (A-4) and (A-7) to calculate the emissions from the soil stockpile and the solid waste burial pile at a time t of 1.25 years for use in the LONGZ model particulate concentration calculations. The emission rate for the soil stockpile was set equal to zero for the three wind-speed categories containing wind speeds less than or equal to 5.1 meters per second and equal to 0.164 grams per second for the three wind-speed categories containing wind speeds greater than or equal to 5.2 meters per second. In calculating the emission rate for the three highest wind-speed categories, the factor f was set equal to 100 percent. The emission rate assumed for the burial pile in the LONGZ model calculations was a constant 0.0423 grams per second for all wind-speed categories.

If the wind-speed factor f in Equation (A-8) is greater than 34 percent, the maximum combined emission rate Q_T occurs at the beginning of the operation of the IGS (i.e., at time t equal to zero). During four of the six "worst-case" 24-hour periods considered in the SHORTZ model particulate concentration calculations, the hourly wind speeds were above 5.4 meters per second for more than 34 percent of the hours. We therefore assumed in the SHORTZ model calculations for these cases that there were no emissions from the solid waste burial pile (not yet in existence) or from the soil stockpile during hours with wind speeds less than 5.4 meters per second. For the hours with wind speeds above 5.4 meters per second, Equation (A-4) with f equal to 100 percent and t equal to zero gives the soil stockpile emission rate as 0.406 grams per second after the annual emission factor is multiplied by 365/295 (the ratio of the total number of days in a year to the number of dry days in a year) to obtain the short-term emission factor. The frequency of occurrence of hourly wind speeds above 5.4 meters per second was approximately 10 percent for the two remaining 24-hour periods considered in the SHORTZ model particulate concentration calculations. If f is set equal to 10 in Equation (A-10), t_{max} is about 1.8 years. After conversion from the annual to the short-term emission factor, Equation (A-4) gives the soil stockpile emission rate at 1.8 years as 0.114 grams per second during the hours when the wind speed is above 5.4 meters per second (f equal to 100 percent) and zero during the hours with lighter wind speeds (f equal to zero percent). Similarly, Equation (A-7) gives the burial pile emission rate at 1.8 years as a constant 0.0643 grams per second for the short-term emission factor.

APPENDIX B

SUPPLEMENTARY METEOROLOGICAL DATA

This appendix lists the hourly meteorological inputs used in the SHORTZ model calculations discussed in Section 3.1. Table B-1 lists the hourly meteorological inputs for the six "worst-case" 24-hour periods considered in the model calculations. All six periods were considered in the 24-hour average particulate concentration calculations. The three "worst-case" 24-hour periods considered in the 24-hour average SO_2 concentration calculations are:

- 1500 MST on 9 November through 1400 MST on 10 November 1949
- 2200 MST on 22 June through 2100 MST on 23 June 1950
- 0900 MST on 23 May through 0800 MST on 24 May 1953

The hourly meteorological inputs for the eight "worst-case" 3-hour periods discussed in Section 3.1 are given in Table B-2.

TABLE B-1
"WORST CASE" 24-HOUR AVERAGE METEOROLOGICAL DATA

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				9-10 NOVEMBER 1949				
15	202.5	8.75	1275	283	0.000	.10	.0465	.1256
16	202.5	8.24	1125	283	0.000	.10	.0465	.1256
17	202.5	8.24	1125	282	0.000	.10	.0465	.1256
18	202.5	11.84	1625	281	0.000	.10	.0465	.1256
19	202.5	13.90	1625	281	0.000	.10	.0465	.1256
20	202.5	11.33	1625	281	0.000	.10	.0465	.1256
21	202.5	13.38	1625	281	0.000	.10	.0465	.1256
22	202.5	12.36	1625	281	0.000	.10	.0465	.1256
23	202.5	10.30	1275	281	0.000	.10	.0465	.1256
0	202.5	10.30	1275	282	0.000	.10	.0465	.1256
1	202.5	10.81	1275	282	0.000	.10	.0465	.1256
2	202.5	9.27	1275	282	0.000	.10	.0465	.1256
3	202.5	9.27	1275	282	0.000	.10	.0465	.1256
4	202.5	8.75	1275	281	0.000	.10	.0465	.1256
5	202.5	7.72	1125	281	0.000	.10	.0465	.1256
6	202.5	11.84	1625	282	0.000	.10	.0465	.1256
7	202.5	11.33	1625	282	0.000	.10	.0465	.1256
8	202.5	8.75	1275	281	0.000	.10	.0465	.1256
9	202.5	11.84	1625	281	0.000	.10	.0465	.1256
10	202.5	10.81	1275	281	0.000	.10	.0465	.1256
11	202.5	11.84	1625	282	0.000	.10	.0465	.1256
12	202.5	10.81	1275	281	0.000	.10	.0465	.1256
13	202.5	10.81	1275	282	0.000	.10	.0465	.1256
14	202.5	12.36	1625	281	0.000	.10	.0465	.1256

TABLE B-1 (CONTINUED)

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				22-23 JUNE 1950				
22	202.5	11.84	2400	296	0.000	.10	.0465	.1111
23	202.5	11.33	2400	295	0.000	.10	.0465	.1111
0	202.5	9.78	2250	295	0.000	.10	.0465	.1111
1	202.5	6.18	1950	294	0.000	.10	.0465	.1111
2	202.5	8.75	2250	294	0.000	.10	.0465	.1111
3	202.5	14.41	2400	294	0.000	.10	.0465	.1111
4	202.5	11.84	2400	293	0.000	.10	.0465	.1111
5	202.5	12.36	2400	293	0.000	.10	.0465	.1111
6	202.5	13.38	2400	293	0.000	.10	.0465	.1111
7	202.5	15.44	2400	295	0.000	.10	.0465	.1111
8	202.5	14.93	2400	296	0.000	.10	.0465	.1111
9	202.5	14.41	2400	299	0.000	.10	.0465	.1111
10	202.5	15.44	2400	299	0.000	.10	.0465	.1111
11	202.5	14.93	4000	300	0.000	.10	.0735	.1310
12	202.5	16.47	4000	301	0.000	.10	.0735	.1310
13	202.5	16.99	4000	302	0.000	.10	.0735	.1310
14	225.0	14.93	4000	303	0.000	.10	.0465	.1009
15	225.0	12.36	2400	303	0.000	.10	.0465	.1009
16	225.0	12.36	2400	303	0.000	.10	.0465	.1009
17	202.5	13.38	2400	302	0.000	.10	.0465	.1009
18	202.5	15.96	2400	301	0.000	.10	.0465	.1009
-19	202.5	15.44	2400	299	0.000	.10	.0465	.1009
20	202.5	10.81	2250	296	0.000	.10	.0465	.1009
21	180.0	8.24	1950	295	0.000	.10	.0465	.1009

TABLE B-1 (CONTINUED)

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				28-29 JANUARY 1951				
20	337.5	6.70	675	270	0.000	.10	.0465	.1246
21	337.5	5.10	460	270	.005	.15	.0465	.1246
22	337.5	5.10	460	270	.005	.15	.0465	.1246
23	337.5	5.70	675	268	0.000	.10	.0465	.1246
0	337.5	6.70	675	268	0.000	.10	.0465	.1246
1	337.5	7.70	675	267	0.000	.10	.0465	.1246
2	337.5	6.70	675	266	0.000	.10	.0465	.1246
3	337.5	7.70	675	265	0.000	.10	.0465	.1246
4	337.5	5.70	675	265	0.000	.10	.0465	.1246
5	337.5	5.70	675	264	0.000	.10	.0465	.1246
6	337.5	6.70	675	263	0.000	.10	.0465	.1246
7	337.5	8.20	675	262	0.000	.10	.0465	.1246
8	337.5	5.70	675	262	0.000	.10	.0465	.1246
9	337.5	5.10	460	263	.005	.15	.0465	.1246
10	337.5	5.10	460	264	.005	.15	.0465	.1246
11	337.5	5.70	675	264	0.000	.10	.0465	.1246
12	337.5	4.60	460	265	.005	.15	.0465	.1246
13	337.5	5.10	460	265	.005	.15	.0465	.1246
14	337.5	5.70	675	265	0.000	.10	.0465	.1246
15	337.5	6.20	675	264	0.000	.10	.0465	.1246
16	337.5	5.10	460	263	.005	.15	.0465	.1246
17	337.5	5.10	460	263	.005	.15	.0465	.1246
18	337.5	7.20	675	262	0.000	.10	.0465	.1246
19	360.0	5.10	460	262	.005	.15	.0465	.0665

TABLE B-1 (CONTINUED)

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				11 APRIL 1952				
0	225.0	2.10	1190	276	.011	.20	.0465	.0665
1	202.5	7.70	1350	276	0.000	.10	.0465	.0665
2	225.0	3.60	1310	274	.005	.15	.0465	.0665
3	135.0	1.50	1060	274	.020	.25	.0465	.0665
4	157.5	4.10	1310	274	.005	.15	.0465	.0764
5	157.5	3.10	1310	274	.005	.15	.0465	.0764
6	135.0	2.60	1190	274	.011	.20	.0465	.0665
7	157.5	5.10	1310	274	.005	.15	.0465	.1009
8	157.5	1.50	1060	274	.020	.25	.0465	.1009
9	157.5	1.50	1060	274	.020	.25	.0465	.1009
10	157.5	3.60	1310	275	.005	.15	.0465	.1009
11	157.5	2.60	1190	275	.011	.20	.0465	.1009
12	157.5	1.50	1060	276	.020	.25	.0465	.1009
13	157.5	4.10	1310	276	.005	.15	.0465	.1009
14	157.5	4.60	1310	278	.005	.15	.0465	.1009
15	157.5	4.10	2500	279	0.000	.10	.0735	.1051
16	157.5	6.70	1350	280	0.000	.10	.0465	.0878
17	157.5	5.10	1310	279	.005	.15	.0465	.0878
18	157.5	5.10	1310	280	.005	.15	.0465	.0878
19	157.5	3.60	1310	278	.005	.15	.0465	.0878
20	157.5	4.10	125	276	.011	.20	.0350	.0575
21	157.5	3.60	125	276	.011	.20	.0350	.0575
22	135.0	3.10	125	276	.030	.30	.0235	.0336
23	112.5	2.60	125	274	.030	.30	.0235	.0336

TABLE B-1 (CONTINUED)

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				29-30 JULY 1952				
19	157.5	3.10	125	294	.011	.20	.0350	.0501
20	157.5	1.50	125	294	.040	.40	.0235	.0336
21	157.5	5.10	1810	294	.005	.15	.0465	.0665
22	157.5	2.10	125	294	.020	.25	.0350	.0661
23	157.5	2.10	125	293	.020	.25	.0350	.0661
0	157.5	3.10	125	292	.011	.20	.0350	.0661
1	157.5	4.10	125	292	.011	.20	.0350	.0661
2	157.5	2.60	125	291	.030	.30	.0235	.0336
3	157.5	4.10	125	291	.011	.20	.0350	.0624
4	157.5	4.60	125	291	.011	.20	.0350	.0624
5	157.5	2.60	125	291	.020	.25	.0350	.0624
6	157.5	5.10	1810	292	.005	.15	.0465	.0665
7	202.5	5.10	1810	294	.005	.15	.0465	.0665
8	157.5	6.70	1950	296	0.000	.10	.0465	.0764
9	157.5	7.20	1950	299	0.000	.10	.0465	.0764
10	225.0	6.70	1950	299	0.000	.10	.0465	.0665
11	202.5	7.20	3700	300	0.000	.10	.0735	.1051
12	247.5	6.70	3700	302	0.000	.10	.0735	.1051
13	202.5	7.70	3700	304	0.000	.10	.0735	.1051
14	202.5	7.70	1950	304	0.000	.10	.0465	.0764
15	202.5	6.70	1950	304	0.000	.10	.0465	.0764
16	225.0	6.20	1950	304	0.000	.10	.0465	.0665
17	135.0	3.10	1810	302	.005	.15	.0465	.0665
18	225.0	5.70	1950	303	0.000	.10	.0465	.0665

TABLE B-1 (CONTINUED)

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				23-24 MAY 1953				
9	202.5	5.15	1310	290	.005	.15	.0465	.1159
10	202.5	11.33	1950	293	0.000	.10	.0465	.1159
11	202.5	14.41	1950	295	0.000	.10	.0465	.1159
12	202.5	15.44	1950	294	0.000	.10	.0465	.1159
13	202.5	13.38	1950	296	0.000	.10	.0465	.1159
14	202.5	15.44	1950	295	0.000	.10	.0465	.1159
15	202.5	18.02	1950	295	0.000	.10	.0465	.1159
16	202.5	16.99	1950	296	0.000	.10	.0465	.1159
17	202.5	15.44	1950	295	0.000	.10	.0465	.1159
18	202.5	16.99	1950	294	0.000	.10	.0465	.1159
19	202.5	11.84	1950	292	0.000	.10	.0465	.1159
20	202.5	13.38	1950	291	0.000	.10	.0465	.1159
21	202.5	13.38	1950	290	0.000	.10	.0465	.1159
22	202.5	13.38	1950	289	0.000	.10	.0465	.1159
23	202.5	14.41	1950	289	0.000	.10	.0465	.1159
0	202.5	13.38	1950	288	0.000	.10	.0465	.1159
1	247.0	7.21	1350	286	0.000	.10	.0465	.0665
2	292.0	8.24	1350	280	0.000	.10	.0465	.0665
3	337.0	8.24	1350	279	0.000	.10	.0465	.0665
4	360.0	4.63	1310	278	.005	.15	.0465	.0665
5	22.0	1.54	125	277	.040	.40	.0235	.0336
6	90.0	1.54	125	278	.040	.40	.0235	.0336
7	CALM - ZERO GROUND-LEVEL CONCENTRATIONS ASSUMED							
8	225.0	9.27	1425	282	0.000	.10	.0465	.0665

TABLE B-2
"WORST CASE" 3-HOUR AVERAGE METEOROLOGICAL DATA

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				25 JANUARY 1949				
13	202.5	1.54	400	260	0.000	.15	.1080	.1925
14	202.5	1.54	400	259	0.000	.15	.1080	.1925
15	202.5	1.54	400	258	0.000	.15	.1080	.1925
				14 JANUARY 1950				
10	202.5	13.38	840	271	0.000	.10	.0465	.0829
11	202.5	13.38	840	271	0.000	.10	.0465	.0829
12	202.5	13.38	840	271	0.000	.10	.0465	.0829
				4 MARCH 1951				
13	202.5	12.87	1950	275	0.000	.10	.0465	.0829
14	202.5	12.36	1950	276	0.000	.10	.0465	.0829
15	202.5	12.87	1950	276	0.000	.10	.0465	.0829
				20 NOVEMBER 1951				
11	202.5	12.87	1625	279	0.000	.10	.0465	.0829
12	202.5	13.38	1625	279	0.000	.10	.0465	.0829
13	202.5	13.38	1625	279	0.000	.10	.0465	.0829
				1 DECEMBER 1951				
22	202.5	4.12	460	277	.005	.15	.0465	.0829
23	202.5	4.12	460	279	.005	.15	.0465	.0829
24	202.5	4.63	460	277	.005	.15	.0465	.0829
				20 JANUARY 1952				
16	202.5	12.36	840	275	0.000	.10	.0465	.0829
17	202.5	12.36	840	275	0.000	.10	.0465	.0829
18	202.5	12.87	840	274	0.000	.10	.0465	.0829
				11 DECEMBER 1952				
9	225.0	1.54	400	275	0.000	.20	.0735	.1208
10	225.0	2.06	550	275	0.000	.15	.0735	.1208
11	225.0	1.54	400	278	0.000	.15	.1080	.1545
				16 FEBRUARY 1954				
15	180.0	4.63	460	281	.005	.15	.0465	.0829
16	180.0	4.63	460	281	.005	.15	.0465	.0829
17	180.0	4.63	460	283	.005	.15	.0465	.0829